University of Oslo
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Positioning Mobile Phones

An exploratory study of positioning technologies and Location Based Services (LBS)

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Cand Scient Thesis

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Abstract

This thesis is a result of a research conducted from August 2003 to December 2004. The subject of research is within the area of information systems research with focus on content services for mobile telecommunication in the GSM network. The main objective is to explore location based services (LBS) by assessing implementations of such upon the characteristics of positioning technologies.

Because of lacking research that analyses the relation between LBS and positioning technologies, an explorative angle is chosen. The empirical studies are based on a case study of LBS offered by Telenor and NetCom on the Norwegian market in 2003. Ways of getting to the data was literature studies, qualitative interviews and technology studies.

The two main sources for theory are Kakihara and Sørensen (2002) and Agre (2001). Kakihara and Sørensen's (2002) mobility types support explorations of LBS implementations. Agre's (2001) conceptual framework for analysis of loosened bonds between activities and place, has helped analyze how locations in LBS are used to support activities.

The research results show that implementations of LBS are influenced by the characteristics of the positioning technologies. The accuracy dictates the level of detail an LBS can provide, and deficient accuracy may create cumbersome implementations based on workarounds. The costs for using an LBS is decisive for some implementations, and may eliminate the potential of LBS with frequent positioning. The topography surrounding a subscriber may alter the performance of the positioning technology, and is therefore an issue that must be addressed when implementing the LBS.

Preface

This thesis is a part of the Candidatus Scientiarum degree at the Department of Informatics, Faculty of Mathematics and Natural Sciences at the University of Oslo. The degree is a combination of one and a half years writing a thesis on self conducted research, and one and a half years of attending advanced courses within the subject.

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Lastly, thanks to fellow students making the everyday life of studying memorable.

Contents

List of Acronyms:

A-GPS	Assisted Global Positioning System
AOA	Angle of Arrival
BTS	Base Transceiver Station
CGI	Cell Global Identity
CGI+TA	Cell Global Identity with Timing Advance
CPS	Cambridge Positioning Systems
E-OTD	Enhanced Observed Time Difference
ETSI	European Telecommunications Standard Institute
GPS	Global Positioning System
GSM	Global System for Mobile communication
LBS	Location Based Service
LMU	Location Measurement Unit
NOK	Norwegian Kroner
MLC	Mobile Location Centre
TA	Timing Advance
TOA	Time Of Arrival
ULTOA	Uplink Time Of Arrival
UMTS	Universal Mobile Telecommunications System

List of Tables:

List of Figures:

Chapter 1

1 Introduction:

The purpose of this thesis is to explore how positioning technologies related to the GSM network supports location based services for mobile phones. Based on the hypothesis that one positioning technology differs from the other with regards to accuracy, cost and behavior in topographical environments, I have tried to enlighten how implementation of location based services are led by the characteristics of the positioning technology. The chosen angle is to assess location based services by evaluating them in relation to the positioning technologies that provide the positions of subscribers.

Location Based Services (LBS) are given by applications that utilize the location of mobile subscribers to decide their content or functionality. An application is a distributed system making use of functions to perform other functions. When an application is installed in the telecom system, it offers a service to some subscribers; in this situation a location based service. Several applications can be combined to offer one service. Acquisition of a subscriber's location is done automatically through technology implemented in the mobile network, called positioning technologies. There are many ways of deciding the location and a certain positioning technology may utilize one or more of them. Examples are; using the cell in which a mobile phone is connected and GPS (Global Positioning System), which can be found in the technologies called Cell Global Identification (CGI) and Assisted Global Position System (A-GPS), respectively.

This chapter will describe the problem statement of the study and previous relevant findings within this area. Furthermore, a presentation of applied research methods along with the thesis' logical structure is given.

1.1 Motivation

The continuous growth of GSM subscribers seems to be over. Figure 1 from the Norwegian Post and Telecommunication Authority (2003) shows that most of the potential mobile phone subscribers have been targeted. There was a strong growth in the number of mobile subscriptions towards the year 2000, but the market is now starting to settle. This indicates that the number of subscribers in the network will be less important for profits for the coming years (Norwegian Post and Telecommunication Authority, 2003) The mobile phone business is thus in a phase where income must be generated from increased traffic in the mobile network rather than from increased numbers of subscribers. Since there is a natural limit to how much subscribers are willing to talk on the phone, network operators thus have to think in new ways. The successful adoption of SMS (Short Messaging Service), with its income stability (Norwegian Post and Telecommunication Authority, 2003) has driven network operators to focus on content services for mobile phones as an area of possible income.

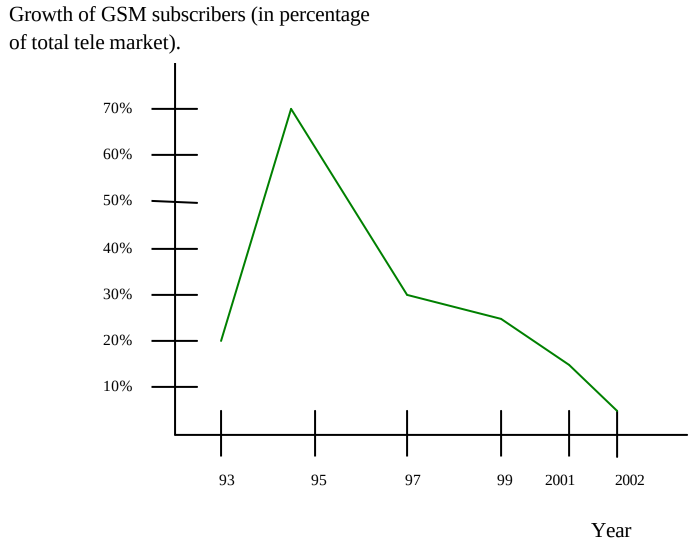

Figure 1: Annual growth of mobile subscriptions in Norway. Measured in percentage of total growth in telemarket, based on numbers from Norwegian Post and Telecommunication Authority (2003)

Due to the mentioned trend, location based services (LBS) are possible revenue sources for network operators. LBS utilize a consumer's position to decide the contents and functionality of the LBS. An important motivator for LBS is the fact that people operate in space and have been concerned with spatial location and surroundings such as where objects are and how to get there for centuries (Smith et al, 2001). Because of their practical appliances, services that use location as parameter (LBS) are expected to be a great success as mobile content services (Mountain and Raper, 2001) (Brasso, 2002). And the Mori institute has conducted a survey (published January 2001) in which 59 per cent of mobile subscribers in France, 52 per cent in the United Kingdom and 42 per cent in Germany expressed a serious interest in using LBS (Siemens 2001, p. 8).

There are several LBS on the market today. Examples of such services are; finding friends, locating vehicles for fleet steering and in case of theft, assist with information on how to find places based on the subscriber's location, and finding nearest restaurant, taxi or ATM.

Personal motivation

Several researches have been conducted on both LBS and positioning technologies. Nevertheless, there seem to be a lack of research that focus on how these entities influence each other. This has been a main motivator for the study. With the lack of existing work, an explorative angle was chosen to find important issues. This study will evaluate the characteristics of positioning technologies and relate those findings to the LBS that utilize the position.

Personal motivation for studying LBS is finding the topic very interesting because of its many possible applications, as well as its futuristic focus. Through added safety and convenience LBS can ideally improve subscribers' lives.
One reason for choosing mobile phones as a focus area is the technology's massive penetration and the fact that subscribers basically carry the phones with them at all times. The way content services are used on an artifact of this penetration can affect how subscribers organize their lives.

It is possible to view technical waves as drivers for LBS. Smith et al (2001) believe that high speed wireless networks, improved mobile terminals and higher accuracy in positioning technologies will lead to improved applications and increased adoption of LBS. General actors in the LBS market are illustrated in figure 2.

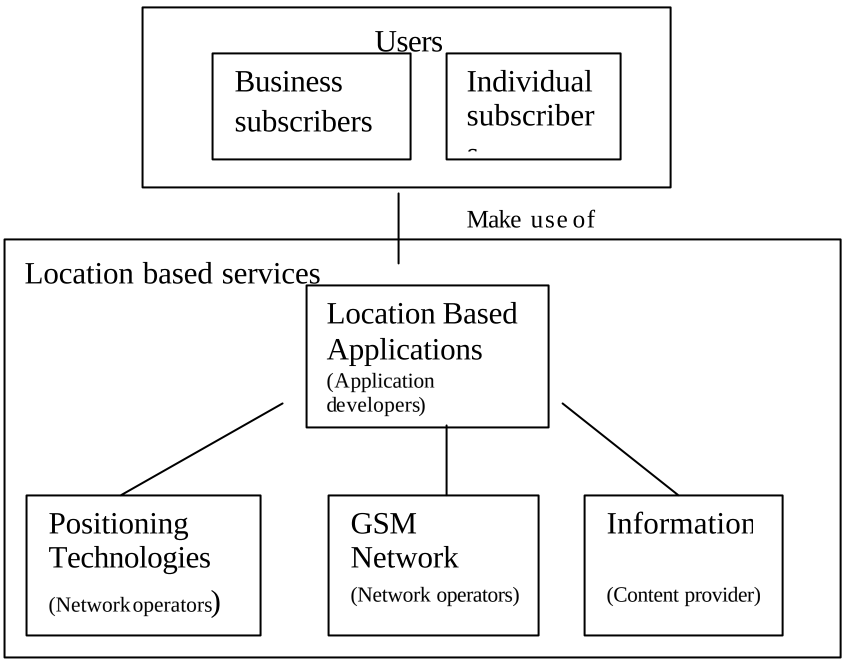

Figure 2: The actors of location based services; enablers, providers and users

Content providers supply resource- and geographic information. Application developers develop and provide applications that present information based on certain input variables. Both content providers and application developers are dependent on the infrastructure provided by network operators to get parameters and communicate results to the subscribers. LBS are the services offered by location based applications, and positioning technologies are commonly implemented as part of the infrastructure given by mobile GSM networks. Different types of LBS, offered by application developers, may have varying demands for accuracy of the positioning (Steinfield, 2003).

Positioning technologies must perform satisfactory in the environments where the LBS they support are meant to be used. Real environments pose many uncontrollable factors, such as the disturbing effect topography has on the accuracy and precision of the positioning technologies. Examples of disturbances are walls that block GPS signals and mountains or houses that reflect radio signals. Accuracy performance in various topographies and costs represented by the characteristics of positioning technologies is manifested in implementations of the LBS.

1.2 Problem definition

This is a study within information systems research and the problem area is rooted in mobile telecommunication. The study considers LBS offered on the mobile telecommunication network in Norway.

1.2.1 Problem statement:

Based on a hypothesis that implementations of LBS are dependent on the underlying positioning technologies, the main research question was found:

> How are implementations of location based services enabled by the characteristics of positioning technologies?

To answer this question, the following three sub-questions were chosen:

1. What characterizes the most common positioning technologies for the mobile telecommunication network?

2. What kind of location based services are offered and how do these services utilize characteristics by the positions provided by positioning technologies?

3. Which limitations do today's positioning technologies pose for location based services and how are such limitations handled or avoided?

With the purpose of attaining a feasible scope, this study only evaluates those LBS offered by the two largest Norwegian network operators; Netcom and Telenor. Use of the term 'implementation' is meant to describe the concrete realization of a location based service. Implementation is the logical means of how certain functionality is assured, for example how something is computed, how input and output is given or how an LBS is invoked.

1.2.2 Approach

The research started with exploring LBS for mobile phones with the purpose of attaining a general understanding of the problem area. Secondly, existing positioning technologies were explored before narrowing the selection to those that locate mobile phones and are most commonly used in GSM networks. The intent was to use characteristics of these positioning technologies to analyze how implementations of LBS on the Norwegian market had been affected by the positioning technologies. In order to compare technologies and keep the evaluation of characteristics on a viable level, three main characteristics where focused on:

-**Accuracy** and **precision** of the position
-How the technology is affected by **topography**
-**Costs** represented by a technology, both for subscribers and network operators

These characteristics were based on France et al (2001), which lists accuracy, topography of usage environment and speed of response as characteristics that yield the quality of positioning. Accuracy and precision of positions are two interrelated characteristics that have a major affect on how location based services are implemented. Lacking accuracy can for example create need for implementations where subscribers manually provide accuracy enhancing information. The positioning technologies are affected by the topography of the surrounding environment, and accuracy and precision may improve or worsen with change in the topography. This change in behavior affects the services that make use of the positions. An illustrative example is how a positioning technology that does not work indoors, may change implementations of LBS or even exclude certain services that are meant to be used indoors. Investment costs decide which positioning technologies network operators choose, and consequently influence performance in LBS. A subscriber's cost for attaining a position is decisive for how often a location based service is used, how it is used and for which reasons (Colibria, 2003). The current study is less concerned than France et al (2001) with the speed of response, as it is normally quite fast and differences are of little significance for the implementation of services (Telenor, 2003) (NetCom, 2003).

The characteristics of the supporting positioning technology decide how an LBS is implemented. If for instance a technology does not support indoor positioning, that technology will probably not be utilized in implementing an indoor specific LBS. Implementations of LBS that are supported by inaccurate positioning technologies, may necessitate manual input from subscribers if the LBS need higher accuracy than the positioning technologies provide. Some LBS are not dependent on high accuracies while the ones that are, must rely on workarounds like manual enhancements of the position.

Observing actual and real life use of LBS is not easy due to their highly mobile nature, making evaluations of actual use a difficult task. By evaluating LBS based upon the support given by positioning technologies in different situations, this study can serve as a reference when developing and implementing mobile LBS. If the performance on accuracy, costs or topography limits the LBS, application developers may benefit by adapting the implementations with regards to characteristics of the positioning technology. Further, the findings can assist the network operators in choosing which positioning techniques to invest in, seen from the way technologies affect solutions and implementations of LBS.

1.3 Relevance to existing research

A current study on LBS, Durlacher (2002), expects LBS to be a key part of future mobile use, the author provides overviews of possible LBS and explanations of how they are valuable. Other researches such as; Steinfield (2003), Kar and Bouwman (2001) study the development of LBS and drivers for these in order to establish opportunities by using location in mobile services. Social effects of LBS are also given, with evaluation of positive and negative outcomes (Basso, 2002). (Beinat, 2001).

There are several studies of positioning technologies; Swedberg (2001), Helgesen (2002), Knardahl (2001), Smith et al. (2001), Mountain and Raper (2001), Lâhteenmâki (2000) and Laitinen et al (2001) are just a few examples. The paper by Swedberg is referenced in much of the literature and seems to be an important source. His paper is actually a presentation of Ericsson's mobile location solution, but provides a good review of; possible technical solutions for providing positioning, LBS and drivers for these. His approach does not compare LBS to the positioning technologies supporting them; instead there is a separate and general overview of the LBS and the different technologies. Another approach on the same theme is offered by Laitinen et al. (2001). This paper gives a review on the status of GSM positioning technologies and predicts near future developments. Field trials of technology have been done as well. Ericsson (1998) and Ericsson et al. (1998) have generated numbers for accuracy and precision by conducting a series of tests for different technology. These studies were intended to help network operators choose which positioning technologies to invest in.

There seems to lack research that connects positioning technologies and LBS, as well as explorations of how they are connected. France et al (2001), Siemens (2001) and Ame Info(2003) include LBS and positioning technologies in their studies, but the interrelation of these is not studied. Beinat (2001) and Wohlert (2000) establish the need to evaluate performance of technologies in light of the LBS they are to support, by illustrating the dependence between LBS and location accuracy. The beliefs behind this thesis are that the chosen angle - assessing attributes in positioning technologies in relation to the LBS that utilize them, will give results that show important performances in positioning technologies based on the context these are intended to support.

1.4 Methods

An explorative study of possible positioning technologies and LBS was done through literature review and interviews. The study is based on the Norwegian market in 2003 and interviews with experts were conducted at Telenor, NetCom and Colibria. Telenor and Netcom are the two major Norwegian network operators and Colibria is an important application developer of LBS. The interviews produced findings and also gave birth to new ideas and issues that were elaborated further. The LBS offered by NetCom and Telenor were used to exemplify and evaluate how accuracy and precision, cost and topography in positioning technologies has decided implementations in the LBS. Many of these LBS were quasi tested, which increased the understanding of how they where implemented in regards to functionality, input and output. Empirical data is based on 1) testing and exploring how LBS are implemented, 2) discussions about positioning technologies and implementations of LBS in the interviews and 3) the literature review of LBS and positioning technologies.

Theories of space and place have been used to explain characteristics of positioning technologies. Mobility types offered by Agre (2001) have helped describe LBS in light of a theoretical framework. By evaluating how the LBS support spatial, contextual and temporal mobility, an increased understanding of dependency between implementations of LBS and the underlying positioning technologies was gained. The capture model was applied to see if other ways of capturing context associated to positions can be found, and thereby evaluate an alternative way of implementing LBS.

1.5 Structure of the report

The report is structured in a way that describes LBS first, by providing definitions and explanations of the LBS offered by Telenor and Netcom. Then positioning technologies are presented and characterizations of these are evaluated. Thirdly, findings related to the research questions are discussed, followed by the conclusion.

1.5.1 Overview of the chapters

Chapter 1 – Introduction, describes the area of research and motivation for choosing this area. The objective of this research and its problem statement is presented. I also give a short overview of the research method which is used to answer the problem statement.

Chapter 2 – Methodology. The study's research method is presented, along with arguments for choosing it. The last part is a detailed report on how I actually carried out my study.

Chapter 3 – Theory. This chapter consists of descriptions of space and place, mobility types and the relation they have to location in content services.

Chapter 4 - Location Based Services are defined, enablers of the LBS are discussed and a categorization of LBS on the Norwegian market is given.

Chapter 5 - Positioning technologies is defined and discussed. There is a summation of strengths and weaknesses, and presentation of technologies found on the Norwegian market.

Chapter 6 - Findings related to the problem area is presented and discussed based on these findings related to the background given in chapter 4 and 5.

Chapter 7 – The conclusion offers a summary of the problem, the main findings and the discussion. There is also a description of how my results fit in with existing research and possible further research related to my findings.

Chapter 2

2 Methodology

This chapter gives an overview of the methods used in the study. Firstly, the philosophical position of the thesis is established, followed by a rationale for choosing a qualitative approach and descriptions of how data was collected in the case study.

2.1 Philosophy behind the methods

Myers and Avison (2002, p. 5) argue that “all research (whether quantitative or qualitative) is based on some underlying assumptions about what constitutes ‘valid’ research and which research methods are appropriate.”

The underlying assumptions of valid research are positivist, interpretative and critical (Figure 3).

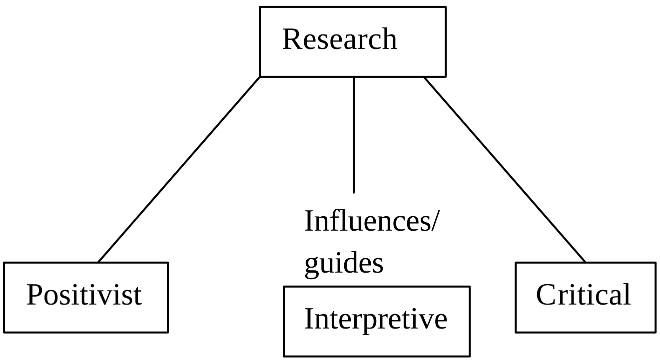

Figure 3: Underlying philosophical assumptions (adapted from Yin, 1994)

2.1.1 Philosophical position in this thesis

Orlikowski and Baroudi (2002, p. 57) classify many existing IS researches as being positivistic, and say that it can be helpful to combine research traditions. By only limiting to one tradition, the researcher has restricted what areas of the IS phenomenon he has focused on and how it is done. The underlying philosophical beliefs in this thesis are mostly reflections of interpretative research, as my assumptions are similar to Orlikowski and Baroudi (2002, pp. 64-67)

characteristics of interpretism. An example of common beliefs is that subscribers create and interpret their own subjective meanings when interacting with the surrounding world. Since the assumption is that there is no objective account of events and situations, the goal is to find a relative but shared understanding of the world to be studied.
Researchers are seldom exclusively part of one philosophy (Braa et al, 2000), and there are also to some extent positivistic beliefs in this thesis. Because of the nature of my problem area and the applied data collection methods, there are occurrences of subjective/argumentative (Galliers & Land, 1987) research in the thesis. With basis in existing literature, opinion and speculation will occur more often than empirical observations. It is therefore important to mix this with other qualified peoples view of the same phenomenon. Interpretative values reflect the varying views within my problem area, depending on the person or instance observing it. For example producers of positioning technologies have other assumptions of the possibilities than developers of LBS that exploit actual data from the positioning. A mix of positivistic and interpretative perspective is hard to realize according to some researchers (Orlikowski and Baroudi 2002, p. 67). Arguments against such mixes are that positivistic perspectives are based on assumptions inherently different from those of interpretative perspectives.

The view on how to generalize findings from this thesis is not absolute. The beliefs are that discovery of certain traits within positioning technologies decide how LBS are used by subscribers and how they are developed. The study has basis from the Norwegian market and include interpretations with assumptions in this market. It is the interpretations and the issues raised that are important to center, and not how valid generalization to other technologies and markets are. The interpretative view of this study makes it hard to draw conclusions and concrete answers to the problem statement, as becomes evident through the discussion. Results are a deeper understanding of the structures in the phenomenon, which shed light to other and similar settings.

2.2 Method types

The usual divide is between qualitative and quantitative research methods, although plenty of others exist (Myers and Avison, 2002).

2.2.1 Quantitative method

A quantitative research method can involve obtaining quantitative data from a representative population sample, and analyzing them. To be able to say something more general about the population represented by the sample, it has to be relatively large. If the sample size is to small, special cases or exceptions may change the results of a research and the normal distribution curve describing that the results are likely to be trustworthy cannot be achieved. Other issues about samples are that they need to be random in order to avoid biased results, while being representative. A representative sample means that the sample contains the same segments and proportions as the large reality a researcher is trying to say something about.

Quantitative methods are used to answer questions that can be quantified, for example finding out how many subscribers that adopt a technology.

Quantitative researchers generalize by saying something about at population based on the empirical data gathered on a sample. This is called **statistical generalization,** and is recognized because of methods to determine the confidence of such generalizations (Yin, 1994). Size of the sample and internal variation within the sample (standard deviation) are such methods.

2.2.2 Qualitative method

Over the last 20 years, qualitative research has become increasingly popular in IS research, and is now accepted to give important insights (Myers and Avison, 2002 p. VII). Qualitative and quantitative methods can also be combined in order to expand and explain results from each of the two.

Qualitative methods are about characterizing. The name suggests that qualities within a topic are of interest. Data sources for this method include observation, interviews and questionnaires, documents and texts. The researcher's impressions and reactions are also considered to be qualitative data. (Myers and Avison, 2002 p. 4). While a quantitative method uses numbers as a basis, texts are considered as the main material for qualitative research. During interviews and case studies, the observations are written in order to use them later. (Repstad 1998, s. 13). A less rigid form in interviews and observations enable the researcher to carry out analysis and interpreting simultaneously with the gathering of data.

The nature of qualitative methods makes for a smaller sample than that for a qualitative. It is the meaning of the content and what the respondents actually say that is of importance instead of how many times some answers reappear.
Qualitative methods are often described as the opposite to quantitative methods, and counting and measuring is considered to have a less important role. However, when conducting a qualitative research it is hard to avoid this completely, as quantifying is such a central role in human thought. What is meant by the less important role is therefore that the systematic use of numbers as an aid in the research is lacking when using a qualitative method. (Repstad 1998, s. 13) Qualitative studies provide explanations of phenomenons with less notion of a black and white labeled world. Instead it can provide conceptual frames and similar. Qualitative studies seldom result in concrete answers or axioms. Typical qualitative studies are concerned with explaining how a phenomenon is, not how many times or where the phenomenon occurs.

Opposed to quantitative methods **generalizations** are not found on basis of statistics. Generalizations are often from case studies or other qualitative methods and a statistical approach would be a fatal flaw (Yin, 1994). Since case studies are not sampling units, generalization should be analytic. With this Yin (1994) means that it compares empirical results with from cases with existing or previously developed theory. Replication may be claimed if two or more cases support the same theory, and even stronger results are found if two or more cases support the same theory, but not a rival theory.

2.2.3 Rationale for choosing the qualitative method

Braa and Sørensen (2000) argue that information systems research on technical objects should be studied in their context, the quantitative method on the other hand, is concerned with cases serving as a replicate of the real world, in example laboratory experiments, surveys and mathematical modeling. The quantitative idea is to test hypothesizes in controlled environments, or being able to say something about a larger part of reality by testing it on a smaller, but representative sample (Myers and Avison, 2002). The aim of this study is to evaluate attributes of positioning technologies in relation to the LBS they are meant to support. It is not interesting to test this in a controlled environment, as I was interested in how technologies perform in real environments and how this affects real LBS. Repstad argues that examining such features, when occurrences are not of interest, observations and interviews should be used (Repstad 1998, s. 19). It could have been beneficial to see how the technologies were used in practice, by observing subscribers in their natural environments. However, this was assumed to be problematic mostly because of the mobile nature of the LBS. Observations would be dependent on the researcher chasing after mobile subscribers for whole days, with the chance that no LBS where used during the periods. The fleet steering applications, represents exceptions of this rule, and could have been studied by observing the service dispatcher that is locally situated. Since there was a need for comparisons between several different LBS, another approach was needed. For that reason it was chosen to assess the LBS and the positioning technologies on the Norwegian market through experiences gained by qualified employees at Telenor, NetCom and Colibria.

The qualitative method describe the “how or what is” in a thorough fashion and is less occupied with the “how often”. Galliers and Land (1987) say that when the problem area is rooted in the complex real world, it is almost certain that a transfer of science laboratory specific methods to the study of IS will be unsuccessful. As mentioned earlier, these are all reasons to choose qualitative methods. But why exclude quantitative methods?

As Nay (1995) says, qualitative and quantitative methods used in combination may provide complementary data sets that together give a more complete picture than can be obtained using just one of the methods. Numerical data can be very supportive in any research, and should not be excluded. Discussions in this thesis

are based on numbers generated by others, e.g. accuracy from quantitative field studies conducted by Ericsson, Telenor, Cambridge Positioning Systems and more. These numbers could have been gathered and tested without relying on existing numbers. However, of essentiality to the method of this thesis is how these numerical data are gathered, it is how technologies affect LBS. Since field testing technology would be time demanding and not central to the problem, data is found through existing documents and interviews. The research is not concerned with gathering such data in general, but what the numbers indicate in meaning of qualitative attributes for technology and LBS in the study. The problem statement seeks to investigate how positioning technologies supports different LBS in the variety of situations imposed by LBS themselves.
Further arguments for not doing quantitative methods:

- It is hard to reproduce the way positioning technologies and LBS behave in context of a real setting into a controlled laboratory. Galliers and Land (2002) argue that studies that do not reproduce the environment are not the most fitted in a real world situation.
- By applying values to variables, factors such as topography that are hard to value, can receive less attention

A comparison of the two methods is given by Cook and Reichardt (1979), represented here in table 2.

What could be gained with quantitative research

If conducting quantitative research in this thesis, I could have found numerical values within the factors technologies are evaluated against, that could be statistically analyzed. Examples where this is potentially helpful, is finding out if subscribers actually found cost and accuracy as inhibitors for using LBS. Achieving such data forces use of surveys since the mobile nature of LBS would make observations difficult. Although this would not answer the question to how it inhibits or changes use, such findings could be useful support in the discussions. Further, the process of quantitative research follows standard procedures that make them easier to generalize and are more objective with less uncontrolled factors.

Weaknesses of qualitative methods

There are, naturally, weaknesses with qualitative research. The result are not statistically generalizable, because of lacking formal methods and a smaller sample. Generalization has to be realized through analytics with comparison of empirical results from cases with existing or previously developed theory. Generalizations of this kind are done based on the theory in chapter 3. Interpretative studies are often subjective and this may be a problem when the reader is not aware of the writer's epistemology. The study is more dependent on the researcher's personal attributes and skills, as it is harder to evaluate the researcher's skills when using qualitative compared to quantitative studies (Ratcliff, 2002)

2.3 Data Collection

Data collection for this thesis was based on case studies, but other qualitative data sources "(…) include observation and participant observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher's impressions and reactions" (Myers and Avison, 2002).

Myers and Avison (2002, p.7) describe four qualitative methods that provide data for the research; case study research, action research, ethnography and grounded theory. Since case study was the qualitative data source of this study, it is described in the following section.

2.3.1 Case studies

Case study is the most common qualitative method in IS research (Orlikowski and Baroudi, 1991). The method is defined by Yin (1994, p. 13) as "…an empirical enquiry that

-Investigates a contemporary phenomenon within its real-life context, especially when

-The boundaries between phenomenon and context are not clearly evident."

Yin (1994) explains that case study is useful in situations where there are many variables of the study, but little data points. When applying the method, the researcher can rely on many different evidence sources and triangulate results. Triangulation of results can be found by using unlike tools to gather information; e.g. interviews, observation and documentation. The theoretical plan should be used to guide data collection and analysis. Benbasat et al. (1987, in Myers 2002) say that the study of information systems in organizations is central in IS as interest has shifted away from technical issues, making case studies highly relevant. On the issue of case studies being positivist, interpretative or critical, Myers argues that it is dependent of the underlying assumptions of the researcher. Yin (1994) is for example positivistic while Walsham (1995) is interpretive.

Validity

Case studies allow capturing reality without excluding important variables. Positivists can however find problems as to generalization, with lacking control over variables and dissimilar interpretations dependently on stakeholders (Braa and Sørensen, 2000). In comparison, when viewing case studies from an interpretative stance, the validity of a case study does not depend so much on being representative in a statistical sense. In this situation, the logical reasoning when describing results from the cases and conclusions from these are central for validity.

The advantages with case studies are that they often illustrate and lead to far more detailed information than a statistical analysis. It is easier to see causalities and context as reasons for outcomes. The main problem with case studies is that they are often hard to generalize, because of the subjective data.

Why case studies are used in this thesis

The initial thought when attacking the problem area was that there was no clear relation between positioning technologies as an observable fact and how LBS are used in their context. This is almost a repetition of the definition of Case Study, and signals how fitting it is to look at existing technology within real context. Another argument was the lacking availability of the data material that could be supportive. Research on theoretical behavior both in positioning technologies and in LBS exists, but it was hard to find actual findings when the two are used in context.

Conducting the case study

When designing the case study it was chosen to make use of a Multiple-Case design (Yin 1994, p 44). By looking at two network operators Telenor and NetCom with different technology and LBS, and one service developer - Colibria, the aim was to gather a holistic view and make comparisons. The data gathering for each case is described below; under literature studies, interviews and technology studies. Typically, a case study researcher uses interviews and documentary materials first and foremost, without using participant observation (Myers and Avison, 2002)

Figure 4, reproduced with alterations from Yin (1994) illustrate how the study was conducted.

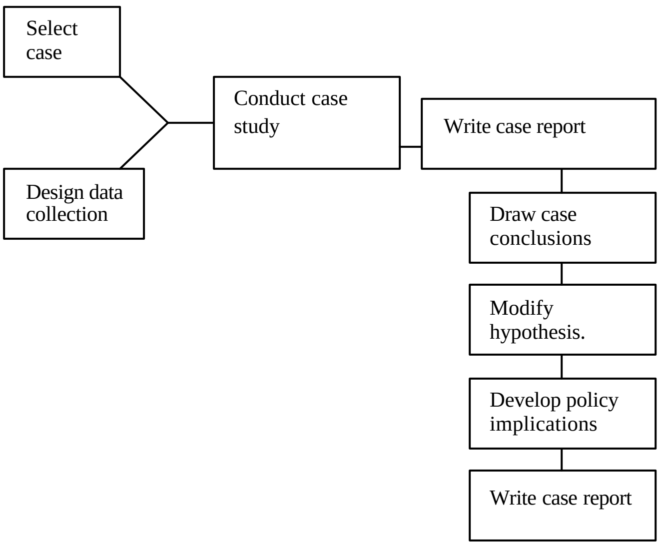

Figure 4: Conduction of the Case study.

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2.4 Applied Methods

Ways of getting to the data was literature studies, qualitative interviews and technology studies. There are two types of literature serving as basis for the thesis; one describing positioning technologies and the other describing LBS. Since the intent is to combine these, a hopeful outcome is that positioning technologies can to some extent be viewed in its actual setting – used by LBS. Interpretative goals are in this way achieved, though not based on empirical observation of actual use. Theory can be used in three distinct ways within interpretative studies; "as an initial guide to design and data collection; as part of an iterative process of data collection and analysis; and as a final product of the research." (Walsham, 1995 p.101). The way literature is used in this study is as a part of the iterative process of data collection and analysis.

2.4.1 Literature studies

"While some materials (data) may be generated by the researcher – as through interviews, field observations, or videotapes – a great deal of it already exists, either in the public domain or in private hands, and can be used by an informed researcher provided that he or she can locate and gain access to the material – or is lucky enough to stumble on it."
(Strauss 1987, p. 3)

There are several ways in which written texts can take part of qualitative studies. First of all the researcher will use literature as a means of getting a good background. Descriptions from existing statistics and other research materials can help form a background for both the writer and the reader prior to a deeper approach. Literature study is a method where certain texts can be given status as sources and data for the research, almost in the same manner as field studies and interviews. (Repstad 1998, p. 86) Furthermore it is useful to relate one's own study with previous and existing work. Written data sources can include published and unpublished documents, company reports, memos, letters, reports, email messages, faxes, newspaper articles and so forth (Myers, 2002). I found it useful to consider the intentions of the writer when using articles as data for my thesis. For example accuracies given by the companies that sell a certain poisoning technology, will often be more optimistic than other sources.

Literature studies became a central part of my work. They helped gain a theoretical background, as well as supporting the cross-reference approach adopted to combine findings on positioning techniques with findings on mobile LBS.

2.4.2 Qualitative interviews

The qualitative interview is much like having a conversation, using open questions and little structure (Repstad, 1998). The interviews were focused on in-depth issues, and tried to avoid rigid forms by using open-ended questions. Interviewing has been accused of being idealistic and focused on the individual, meaning that the researcher may pay too much attention on one person's meanings. This critique is important to bear in mind when analyzing and interpreting the material. The interview guides were made to cover central aspects related to the problem statement, while trying to avoid closed questions. As a result, several interviews revealed issues that were not in the interview guide but still important. It was found important to follow up these kinds of answers so that the subject could expand and explain their statements.

As the informants had different backgrounds, it was useful to adapt the interview guide and make changes to fit the situation. As the research progressed, some questions were answered, causing a shift of focus and emphasis on unanswered questions in the guides.

In order to know what to focus, the interviews started with a request for a description of the interviewee's research or work. When they finished explaining, a short overview of my thesis was provided, while trying to obtain their comments on my approach.

2.4.3 Technology studies

Studying technology has also been part of my study. In order to understand how both simple and advanced mobile applications are in use, a professional mobile phone was purchased so that all such applications could be tested (including wap and java). This study of technology gives me a better background and a wider perspective when examining my problem area. This can to some degree be seen as similar to quasi-experiment (Braa and Sørensen, 2000). As no explicit control of experimental variables, randomization and multiple treatments were done, technology studies are not treated as experiments in data collection. However, by specifically testing and using Location Based Applications over time, some valuable experiences where gained. Among those were how the interface worked both in regards to queries and replies. How exact the description of where objects are located, compared to the accuracy of the positioning technology in use. This says something about how a subscriber can perceive positioning; in example when an LBS replies that a subscribers is located in Homansbyen, an accuracy of 150 meters is not exploited. By the provision of a map in the same service, when accessed through the World Wide Web, accuracy of the technology was experienced quite differently. The technology studies also gave me a general understanding of how the mobile LBS on current markets works in practice.

2.5 Analysis

"Data do not speak for themselves"(Repstad 1998, p. 93 translated from Norwegian), they have to be analyzed. With this, Repstad means that a researcher has to go over data and evaluate, compare and present data according to what they are meant to say something about.
The data for this study are mainly literature and findings from qualitative interviews.

Even though it can be said that analysis, interpretation and writing often are done simultaneously, they are distinct activities. When arranging data so that they can be interpreted, the researcher is actually analyzing. Interpretation is both evaluation of the data and literature and theories, related to the research problems. Writing the report is a mean for sharing the findings with the reader.

In qualitative research emphasis is neither on statistics nor other mathematical methods. Strauss (1987, p. 3) argues that qualitative researchers often use the same pragmatic analytic method as everybody when thinking about everyday problems. When conducting scientific research, on the other hand, it is important to be more self-conscious and thorough.

The last analysis of this study included cross-referencing findings in user centered aspects, positioning technologies and types of LBS along with their various positioning demands.
In this work it was important to get input from qualified human resources. By conducting interviews with scientist, academics and professionals, I got the chance to learn more and evaluate my own assumptions from the preface and research.

Chapter 3

3 Theory

This chapter features important theoretical foundations that are used to support analysis and findings in this thesis. The two main sources for theory are Kakihara and Sørensen (2002) and Agre (2001). Kakihara and Sørensen's (2002) mobility types have helped explore implementations of LBS. An increased understanding of dependency between implementations of LBS and the underlying positioning technology was gained by evaluating how the LBS support spatial, contextual and temporal mobility. Agre's (2001) conceptual framework for analysis of loosened bonds between activities and place has been applied to the LBS explored in this thesis. This framework has clarified the mappings between activities and places, and thereby shown how locations in LBS are used to support activities. The capture model (Agre, 2001), was employed with the purpose of illustrating an alternative way of capturing context associated with positions. Lastly, this chapter describes the factors that positioning technologies and LBS are evaluated upon. These factors are topography, cost and accuracy.

3.1 Space and place

The two terms 'space' and 'place' are not used as a theory, but the terms are important for evaluations in the thesis, especially for positioning technologies. Further, space and place are central for understanding the applied theories.

"Space is the opportunity; place is the understood reality"
(Harrison and Dourish, 1996)

3.1.1 Space

The term space describes the area, without interest in the physical surroundings, that a person or object moves around in. We organize space with explanations such as down, up, front and back and the explanations give the same meaning to others as the world is structured in the same way for everyone. Space is what enables Kakihara and Sørensen's (2002) spatial mobility and does not give any meaning to people in itself, but the surroundings in specific areas of space can represent meaningfulness.

3.1.2 Place

A spatial location with meaning is called a place, and is dependent on surroundings and the context of a location. Harrison and Dourish (1996) explore the differences between the two terms in their article. They explain space as part of the three dimensional world in which we live, and place as a space with an appropriate behavior. Activities are linked to places; people work in offices, people do not speak in the theatre and we eat in restaurants. Space can change in the meaning of place without changing its physical properties. For example, a restaurant as a location can easily be used for working instead of eating.

3.1.3 Capturing contexts in a place

The terms position and location are used throughout this thesis, and may seemingly describe the same phenomena. However, there is a conscious choice of when they are used. The term position is used to describe a small area of space, with no other meaning than spatiality. Positioning technologies are only concerned with positioning without other meanings than physical whereabouts in space. When this information (position) is utilized to generate a meaning in LBS, the term location is used. Location is therefore a reference to place, while position is a reference to space.

The terms ‘space’ and ‘place’ are seen as parts of the term location. A position can be given in space without referring to the place, in example object A is at location -119.72 degrees west 36.82 north. The way the term place is used in relation to positioning technologies and LBS is; that a spatial position matched with geographic information gives meaning as a place. An example of a place in this sense is that the mobile terminal is next to a certain ATM or a restaurant. Since places are made up of many context parameters such as buildings, social norms, people and activities it is hard for an information system to automatically capture a place and all of its contexts. LBS for mobile phones can only capture a part of the context by attaining a subscriber's position in space and using it as a reference to give meaning – or a notion of place.

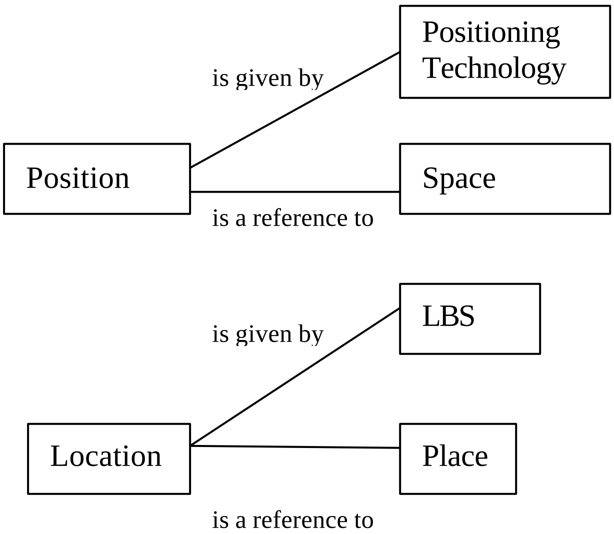

Figure 5: Illustration of how location and position is related to positioning technology, LBS, space and place

3.2 Mobility types

The types of mobility LBS support has been identified with help of Kakihara and Sørensen's (2002) spatial, contextual and temporal mobility. With identification of such support, it has been easier to see how the LBS utilize positions. Secondly, notions of how implementations are affected by characteristics in the positioning technologies are given.

A simple understanding of mobility is that it describes the movement of people (www.dictionary.com), and space is therefore enabler for mobility. Kakihara and Sørensen (2002) argue that current debates are too focused on functionalist analysis of how mobile technologies may ease geographical hindrances for people. Their paper therefore discuss mobility as the interaction between people, based on analysis of three aspects of mobility; spatial, temporal and contextual mobility. The relevance of space and place in these mobility types is that spatial mobility explains people's and object's movements space, and contextual mobility explains peoples movement in the surrounding area – places. Contextual mobility can also describe change in the places themselves. Temporal mobility explicates that spatial mobility can remove dependencies between activities and places, resulting in less demand for when an activity must be done. Kakihara and Sørensen (2002) explain the three mobility types in the following way:

3.2.1 Spatial mobility

Spatial mobility is used for describing geographic movement of people and objects in space. Mobile phones push spatial mobility as it enables subscribers to be reached almost independently of where they are located. Further, information can travel over mobile networks or the Internet and it is also independent of location. Computer and mobile phone mediated communication between subscribers takes away geographical distance as an inhibitor for communication. Spatial mobility is actually what makes an LBS appealing, as the location of a subscriber would not be that interesting if it was static or the environment did not change.

3.2.2 Temporal mobility

Temporal mobility is concerned with the time when an activity is supposed to take place. This kind of mobility is supported by use of technology such as mobile phones because they support activities on the fly, resulting in less planning of activities with less temporal demands for when the activity must take place.

3.2.3 Contextual mobility

Contextual mobility says something about the context for which an activity takes place; in what way, in what circumstance and towards which actor. Contextual mobility reflects how subscribers interact under certain circumstances, and the mobile phone decreases contextual dependencies. Different contexts can be the mood of a person, cultural background and the degree of mutual recognition. By enhancing contextual mobility, obtrusiveness becomes a central issue, and Kakihara and Sørensen (2002) says that obtrusiveness is greater if a person is confined to notice or react to an interaction. Information and communication technologies (ICT) give subscribers opportunities to interact in different ways and therefore increase contextual mobility.

Kakihara and Sørensen's (2002) spatial and contextual mobility can potentially take away important parameters that people are used to have access to. Although it is useful with increased contextual and spatial mobility in many situations, the mobility can actually make access to information about location and context of a person very hard. Mobile phone subscribers are less bound to geography and this makes it harder and possibly more relevant to know a persons location and context, especially when trying to find someone and/or their contextual setting,
LBS can automatically decide were a person is in space and when this position is matched with information about the area, a place with some with meaning relevant to the position can be found, representing a portion of the subscriber's context.

3.3 Architecture, practices and institutions

Agre (2001) argues that technologies like mobile phones have taken away the bonds between activities and places. Further, he says that:

> *"As all of one's relationships can be continually present, divided attention becomes the rule. The mapping between activities and place will dissolve, and everyplace will be for everything all the time."* Agre (2001, p. 5)

This loosened bond makes it is hard to analyze context for context aware systems (Agre, 2001). In order to analyze these phenomena, Agre (2001) has proposed a conceptual framework based on architecture, practices and institutions. This thesis will use the framework as a way of exploring how LBS support mappings between activities and places. This will help demonstrate how position is used in LBS to give support for activities.

Architecture - is the built environment such as buildings, walls, doors and windows.

Practices – are the routines a particular community has for doing activities in place. Agre's (2001) examples are how a married couple greet when arriving from work and the social rules when attaining a theatre.

Institutions – are the social roles and rules of human relationships. Examples of institutions are marriage, family, stock market and the rules of driving on the highway.

The three terms elaborate on contexts of subscribers and help describe places. Architecture and institutions are long lasting and impersonal, and together they decide the evolution of practices. Although institutions and architecture are interconnected and impose mappings between activities and places, this picture is changing. Mobile phones are continually present and allow any institution to structure activity in any place. Agre (2001) provides the example of mobile payment, bringing the institutions of banking and commerce into every place. In a situation where almost everyone has a mobile phone, these devices can interact by connecting to each other, to information sources such as databases or to other local devices. Agre (2001) provides architectural and institutional aspects of context for use in context aware computing. When mappings between architectures and institutions break down, physical places will be able to play roles in many institutionally organized activities, but space will not be able to provide detailed prognoses in LBS.

The view in this thesis is that LBS can, to some degree, provide subscribers with information about the place for which an activity is to take place.

3.4 Capturing place as context

Agre (2001) provides a second framework; a way of capturing context for context aware applications – called the capture model. While most of the LBS explored in this study use position as a rough estimate to capture place, the capture model was used to exemplify an alternative.

How the model works

Institutions can structure the context of the ongoing activity and the social relations within which the activity is embedded. People also use many features of a physical environment for social construction, but only through this ongoing construction a place is found – for example a meeting room instead of just a room. A device that cannot capture the same social construction will have problems with registering even basic aspects of context (Agre, 2001). Agre's solution is to restructure the activity itself so that it is easier to capture the relevant aspects, a method he calls the capture model. The capture model provides a method for integrating computer systems into social systems through analysis, articulation, imposition, instrumentation and elaboration. The idea is to **analyze** an activity and reduce it to smaller elements **articulated** in a grammar representing institutionally permitted sequences of action. Through **imposition** the articulation is put in everyday life of the institution, **instrumented** by a system and utilized for several purposes in **elaboration**.

Mobility / Position	Spatial mobility	Contextual mobility
Space	Space is an enabler for spatial mobility. Spatial mobility is a subscriber's movements in space.	A subscriber's movement in space creates contextual mobility. However, the term space does not pay attention to context.
Place	When a subscriber moves in space, he shifts locations from place to place. Spatial mobility is not concerned with the meaning of each place.	Place is a space with meaning. Contextual mobility is a situation where either a subscriber is moving between places or the surrounding environment is changing. When explaining the relation between places and activity, helpful terms are architecture, institutions and practices.

Table 1: The relation between the differeent terms from applied theory.

3.5 Attributes in the evaluation

With the purpose of comparing different positioning technologies and LBS certain attributes where chosen. The attributes focused in this study are:

1. **Topography**
2. **Cost**
3. **Accuracy**

The choice of attributes for evaluating the support given by positioning technologies to LBS, was based on attributes that existing literature argue is decisive for quality of service. France et al (2001) list accuracy, topography of usage environment and speed of response as characteristics that yield the quality of positioning. Speed of response is normally quite fast, at less than 15 second for almost all positions, and is therefore not discussed in depth. Hightower and Borriello (2001, in Steinfield 2003), mention cost as a means to distinguish between positioning technologies. As cost is believed to decide implementations of LBS, it was chosen as one of three attributes.

3.5.1 Accuracy

The **accuracy**, also called resolution, of a positioning technology describes how fine grained a position can be give n. It is often given on the form accuracy>100m, and meaning in this example that a position where the object positioned (often a subscriber) is given with an error margin smaller than a 100 meters. Since several of the network based technologies can decide which sector a subscriber is located within, the error margin will not typically be a radius, but often an arch. A precise description of accuracy is provided by Wohlert (2001, p.11); "the difference between the actual and estimated location". The **Precision** of a certain technology portray how often the technology gives a correct position, or how often a degree of accuracy can be given. Specific numbers for precision of the various technologies were not available during the work on this thesis, but I have tried to reason for causes that may affect precision for the respectable technologies based on how the technology works

3.5.2 Topography

Topography is used for describing "the configuration of a surface and the relations among its man-made and natural features" (www.dictionary.com). It is understood as physical appearances of the area the technology is meant to cover understood. Radio waves can change their direction as a result of reflections in the landscape and may even be blocked by obstacles such as buildings or mountains. It is therefore central to ask questions such as: Are there many buildings that can block signals? Are there high occurrences of BTS's? Is the subscriber going to be indoors? And so on. The topography has a great influence on accuracy and precision of the different solutions, and may therefore change implementations of LBS.

3.5.3 Cost

Cost of implementing technologies in the mobile network is decisive for the operator's choice of technologies. As Europe does not have any similar drivers to the U.S. E911 mandate, investments in positioning technologies becomes a matter of cost and benefit (Beinat, 2001). Different implementations have varying costs, both with regards to investment and maintenance (Steinfield, 2003). Another interesting issue is finding out who should carry the costs. If network operators invest in network based technology, they probably intend to get return on investment from increased traffic on the network or fixed prices per positioning. If changes are to be made on the mobile terminal, manufacturers of these must raise prices and they will probably generate more income from sales terminals. This illustrates how subscribers are imposed by the different technologies, and can in turn inflict how they utilize the LBS. If the cost from each position is to high, certain LBS may have less usage. For example an instant messenger with continuous updating of position for the subscribers in a friends list will not be feasible if each position costs NOK 5,-. (Colibria, 2002), causing too high usage costs for subscribers.

3.5.4 Other relevant attributes

The main three attributes will now be explained and set in relation with some of the 6 attributes that Hightower and Borriello (2001, in Steinfield 2003) provide as a means to distinguish positioning technologies. These are attributes that help create a background and thereby improves understandings of both LBS and positioning technologies.

Physical versus symbolic location is explained by Hightower and Borriello (2001). It is much akin to what others calls space and place (Dourish and Harrison, 1996)(Agre, 2001). A physical location is given in terms of coordinates (latitude, longitude), and can be found in technologies like GPS and E-OTD. Symbolic location gives a notion of place, such as being in a certain building or a city. It should be noted that physical location can be transformed to a symbolic location if it is matched with information for that location. Symbolic locations are not represented in any of the positioning technologies, but are values that can be computed when matching a position with geographical information for locations. Example of the latter is representing physical locations with certain behavior, making the phone perform predefined tasks when within range of specific cells in the mobile network. In this solution, these cells will represent locations with symbolic meaning. Because symbolic location is seen as application dependent and not technology dependent, positioning technologies are not evaluated upon this variable, but it is used for discussions about how the locations based services perform.

Absolute versus relative location is somewhat similar to that of physical versus symbolic, where an absolute location can be either physical coordinates or a symbolic name. Some technologies are more interested in relative position. That is the position of one object or subscriber relative to the other. LBS supported by such technologies are often triggered by proximity to objects, e.g. a subscriber to another when they pass each other, or the distance between a subscriber and an ATM machine. Technology that is not of such nature that provides relative positions can still support relative location, when calculations of absolute positions are cross-referenced. Bluetooth is the only positioning technology focused in this thesis that supports sensing of a location relative to something else, e.g. point of interest or subscriber. It will be several years before it is used for location detection purposes (Telenor, 2003) and relative location must therefore be computed in the applications. Relative location is assessed in discussion chapter (chapter 6) and under indoor positioning technologies.

An interesting observation is that all the positioning technologies actually computes a position by comparing the mobile phones relative position to known object such as cells, base transceiver stations or satellites. After finding where a mobile phone is located relative to the object, this position is compared to the objects absolute position and the mobile phone’s absolute and physical position is found.

Localized location computation is done in technologies where mobile terminal itself calculates the location (often aided by the network). In this situation, position is revealed only when a subscriber wants to, hence offering increased privacy. While GPS based positioning is an example of localized location computation, network based technologies like CGI and UL-TOA always expose a subscriber’s position to the mobile network. This characteristic will not be a key factor evaluated in the discussion of how positioning technologies support development and use of LBS, but will aid in describing technology against the other factors especially when assessing recognition (chapter 6.5).

Coverage area or what Hightower and Borriello(2001) call **scale** is another important trait that can help classify location techniques and show how they support LBS. The two terms express the size of the area for which a certain technology can support adequate positioning. Examples of different technologies that yield different coverage area are traditional GPS with worldwide coverage Steinfeld (2003), CGI+TA that might focus on a country, down to Bluetooth which gives location within buildings. One way of representing scale is that recommended by Hightower and Borriello (2001); in terms of the coverage area per unit of infrastructure and the number of objects that can be located per unit and time interval. Coverage area is used mainly for describing attributes of technology as to how they inflict cost.

Recognition, although not being the most important to this thesis, describes and signifies the technology. When location data is matched with a certain behavior for a specific subscriber, recognition is achieved. Traditional GPS is an example that does not support recognition, while most network based technologies and even A-GPS can be configured to support it. Recognition is highly likely to be an implemented part of a mobile network, as it is needed to assess whether someone is a registered user of LBS or not (Steinfield, 2003).

An interesting observation is that the attributes explained above are highly interconnected. In positioning technologies that has increased one of the attributes, other attributes are decreased, for example increasing accuracy gives a poorer precision and higher cost. As will be shown in the following discussion, this dependency affects the way positioning technologies support LBS for varying purposes and situations.

Chapter 4

4 Location Based Services

This chapter defines and describes location based services (LBS). Further, contributing factors and drivers for location based services are discussed, and the LBS are evaluated in relation to space and place. Categories for the LBS' studied in this thesis along with descriptions of the specific LBS are presented and related to theory.

4.1 Definitions

Said simply but maybe imprecise, location based services focus or base the information they present dependently of a person's or an object's location. Caslon Analytics (2003) define Location Based Services (LBS) as those:

> "(…) that exploit the ability of technology to know where it is, and to modify the information it presents accordingly. LBS technology is inherently distributed, mobile, and potentially ubiquitous."

Before exploring the subject of LBS, a more precise definition is needed for describing how the expression is used throughout this thesis. There exist many variants that emphasize different aspects, some focus on how and when the position is found and others on how it is used. The reason for this diversity is probably the large range of LBS available and their features. Davies (2000, in Smith et al. 2001, p. 2) has the following definition:

> *"Location Services deliver information about the geographic location of mobile telecommunications devices. This includes mobile telephones, mobile interactive browsers and devices attached to other moveable items such as people, packages and vehicles. Location Based Services deliver end-user applications based on Location Services."*

The advantage of this definition is that it explicates the geographic basis of LBS, often called **physical location**. It also describes users, both people and objects, as well as devices used for access to LBS. The definition focuses on the device that is positioned and gives different examples of these. For the current thesis, the only relevant device positioned by positioning technologies is the mobile phone, either normal or especially tailored such. Lacking is in Davies's definition is the notion of **proximate location –** a person's or object's location in relevance to other people or objects, meaning that the LBS is not always exclusively concerned with where a person or object is geographically.

Van de Kar & Bowman (2001, p. 3), have another view of LBS's and describe:

> *"Location Services as mobile telecommunication network-based services that are accessible by a mobile station and that use the automatically determined location of the mobile station"*

The problem with this definition is that it does not clearly include positioning from technologies that are handset based, by saying that LBS are network-based and that they get location from the mobile station. Further, it does not clearly state that the LBS can be dependent on information in the mobile terminal and the mobile network. As the view in this thesis is that technologies that are handset based (like Bluetooth and enhanced observed time difference (E-OTD), explained in chapter 5) can support LBS, a definition that includes these must be used.

A Location Based Service, as used in this thesis is defined as:

> *"The service given by an application that utilizes the location of a mobile phone to focus the contents of information or functionality offered by the service"*

A clarification of the difference between a service and an application may be appropriate as these two terms are used to describe different manifestations. An **application** is a distributed system consisting of a set of objects interacting, making use of functions to perform other functions. When an application is installed in the telecom system, it offers a **service** to some users; in this situation a location based service. Several applications can be combined to offer one service.

LBS are enabled by the positioning technologies giving a position and the information containing geographic references (see figure 6).

Positioning technologies

Any positioning technology that gives position of mobile phones automatically without manual input of location data is valid for the definition above. The focus on specific technologies in this study is merely a result of keeping the size of the problem feasible.

Types of positions

Position can be both a physical (absolute) or relative/proximate position. Absolute physical positions are often given as a Cartesian reference with X and Y values representing axis' in space. Normal values are Latitude, longitude (in degrees, minutes, seconds). Relative positions are not concerned with where something is in space, but it takes interest with situations where the object is proximate to something or how it is relative to another object. Although proximate positions are different of nature from physical positions, they can be calculated by the latter when combined with Geographic Information (and vise versa).

Geographic Information

The importance of the information presented by LBS is that it gives extra value to the LBS if it is matched with geography-specific attributes. Such information is commonly distributed by third party providers and is called Geographic Information. Geographic information is information that is linked to specific areas, for example databases that hold ATMs and their spatial positions or historic information about a specific area. The fact that the information is linked to spatial areas makes is possible to refer to the information via spatial positions. Geographic Information Services have been around for a while and are services that enable subscribers' access to Geographic Information. Through automatic position detection, location can be used to filter access to these, giving a range of LBS's with added value. By combining position information (of the subscriber's whereabouts) with spatial and non-spatial databases or other information services, extra value can be given to the subscribers. Databases holding information on location of a mobile subscriber or another object are also important information sources that enable LBS.

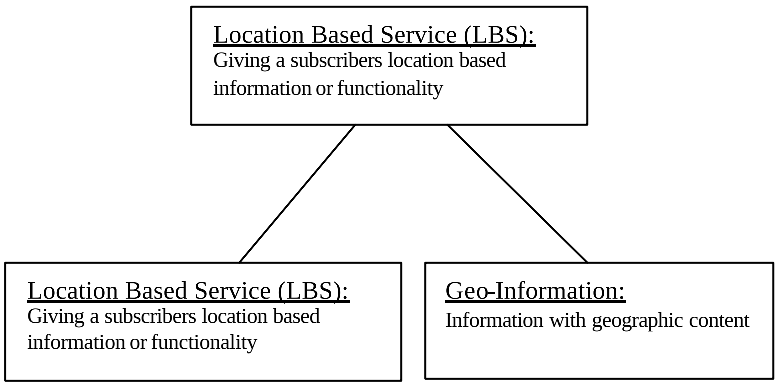

Figure 6: Positioning technology and Geographic Information enables LBS

4.2 Parts of LBS

When utilizing the location of a mobile phone to focus contents or functionality it is understood that the services "... involves the integration of communication systems and databases that either use information that is specific to a particular system (eg participants in an automated traffic payment scheme) or draw on - and often enrich - information from other sources" (Caslon Analytics, 2003). Said simply, network computing – getting access to information in databases through the mobile network, enables access to information and positioning technology enables positioning for LBS (see figure 6) Caslon Analytics (2003) argue that LBS involve integration of communication systems and databases that make use of information specific to a particular system or information from other sources. The most important LBS user tool is the mobile phone, but PDAs and lap tops can also use these LBS. This thesis will, however, focus on mobile phones using the mobile telecommunication network (GSM/GPRS), and the terms mobile terminal and mobile network will only concern these respectively. Network computing with databases filled with information, a subscriber or other object's position acquired by positioning technologies and the mobile network for communication of the position and the information, are enabling factors for LBS.

LBS manage geographic information and deliver request from customers to the appropriate service providers. These LBS are not dependent on the type of positioning technology used; they just need a fairly good accuracy of the geographic coordinates (Lacy et al, 2001 p.9). Because of network computing a subscriber can access information stored elsewhere than the mobile phone. Provision of information linked to locations can, although not reaching its market potential yet, already provide LBS such as finding nearest ATM and simple navigation. (Smith et al 2001). In order to provide consistent and complete spatial information, many countries are building Spatial Data Infrastructures (SDI), infrastructures for land and geographic information. The infrastructure provided by SDI has proven to be a useful and necessary mechanism for LBS (Smith et al, 2001), as LBS can retrieve exact information in a secure manner.

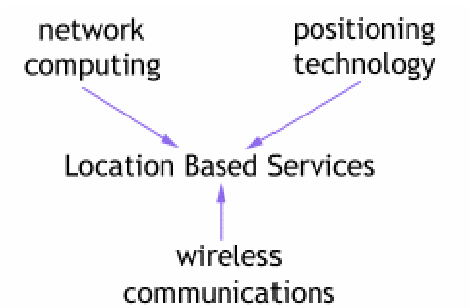

Figure 7: Contributing factors for Location Based Services

4.3 The importance of space and place

LBS are based on applications developed either by the network operators themselves, or more commonly by third party application developers. LBS use a position in space to decide the contents of the service. Application developers are in this way using space to capture certain contextual parameters in a highly contextually mobile situation. Since positioning is done externally from the application via positioning technologies, location based application developers should have contextual mobility and temporal mobility as primary focus. Understanding why, where, how and when subscribers use an LBS is relevant for application developers, and if no surveys are available, assumptions must be basis for such understanding. It is for example possible to predict that subscribers in need of a taxi either are or will be on the move, and thereafter use this assumption as basis for design choices in an LBS that finds the nearest taxi. Referring to chapter 3 (theory), contextual mobility is about the context and the place for which an activity s done; it is in what way, in what circumstance and to which actor. When developing mobile services to support subscribers that find themselves in many contexts, it is useful to understand the contextual mobility of potential users. Temporal mobility is connected to contextuality and is relevant to development of LBS in that the mobile phone supports communication and information access across time and place. Less time-planning from subscribers generate a need for timely information and functionality that can be delivered by LBS. By comparing positions with information specific for surrounding areas of the position, LBS to some degree present a notion of place in the space occupied by a consumer.

Subscribers that make use of LBS are affected by spatial, temporal and contextual mobility. Because of people's changing contexts caused by movements in space, the contextual surrounding is relevant for subscribers. LBS in fact tell subscribers something about their surroundings and place, directly or indirectly. An example where a perception of the context and the place is given directly is in situations where the subscriber is informed about the surrounding environment (by the LBS), for example where restaurants are located relatively to the subscriber. In an indirect manner, subscribers can be receive place specific functionality and information without knowing that their position or surroundings are used to decide the functionality or information of the service. An example is when a subscriber's call is routed to the nearest department based on their position when calling the police. In such LBS, the subscribers do not need knowledge about the surrounding area as the application provides the information relevant for the area.

4.4 Drivers for LBS

The consumer's wish for more personalized information and features, increased communication convenience, safety and security are key drivers for their increased interest in LBS. (Schneider, 2000) (Smith et al, 2001 p. 7). Making information personal and relevant is not an easy task, but by using location as a parameter it is possible to increase relevance. For instance when accessing information about where to find ATMs, it is more personal and relevant to focus on the ATMs in nearness to the subscriber's location. Increased communication convenience can be supported simply by knowing where a person is before calling, and in example trying to arrange a meeting one might exclude persons that are out of town.

The feeling of **safety** is important for most people, and because of an enhanced 911 (E911) ruling by the US Federal Communication Commission (FCC) safety has become a key driver for LBS. The ruling pushes American companies in developing positioning technologies of higher accuracy. Phase one requires carriers to report the telephone number of a mobile 911 caller and the location of the antenna that received the call. In the second phase, there are specific demands to provide far more precise location information of the person calling - within 50 to 100 meters in most cases. (Federal Communication Commission, 2003). This ruling is intended to take away the need for manual self-location when calling emergency services, and aid emergency personnel in directing help to the correct location. In Europe, 112 was established as a universal emergency number in 1998. Enhanced 112 is to some extent similar to E911, and there have been suggestions for accuracy demands by the European CGALIES. Caller finding is important and the report (CGALIES, 2002) says that accurate determination of an emergency caller's location shall be provided to help rescue personnel finding the victim as fast as possible.

Many think of the mobile phone as a good safety provider, since it enables contact with the outer world in critical situations where help is needed. Network operators are currently using safety as an argument in TV commercials, as one commercial (for Telenor) shows a broken down car and a wish list containing a can of gas and a mobile phone. In addition to emergency, other safety-directed LBS are roadside assistance in case of car breakdown and safety alarm for elders or threatened (Helgesen, 2002). Apart from Emergency, commercial aspects are a recognized driver for LBS, especially in Europe where the E911 ruling does not impose demands (Swedberg, 2001). Reduced costs through optimization, differentiation through exiting new products and increased revenues are most important reasons for operators to invest in positioning technologies according to Swedberg (2001).
LBS are not exclusively advantageous for society or individual. Important disadvantages can be found within privacy, as people often are reserved when giving consent to being located or even worse tracked by others (Norwegian subscribers must give consent if they are to be positioned). The worst case

scenario can be reflected with the “big brother is watching you” view of George Orwell’s book 1984. Most people are reserved when giving consent to being located by services, possibly because we are afraid that the information may be misused. A news article written by Batista (2002) named “Your Boss May Know Where You Are” puts attention to the issue of privacy and how it can disadvantage people located with LBS.

There are many LBS in today’s market; such as services that find information relevant to a person’s location or simply finding the location of another mobile phone subscriber. Examples of the latter are Buddy and Kompis, while Taxi and Weather are LBS that find relevant information based on the location of a subscriber. Relevance in this meaning is on utility and it can be assessed on basis of how information meets the needs of the present situation (Bates, 1996 in Nielsen, 1999), or the present context (Nielsen, 1999). McCabe (1999 in Smith et al, 2001) see great potential in LBS as it benefits both subscribers and network operators. For network operators, LBS help “differentiate services portfolios, improve network efficiency and create greater pricing flexibility to address discrete market segments” (Smith et al, 2001 p. 7).

4.5 Categorizing Location Based Services

The two Norwegian network operators Telenor and NetCom, endorse different types of LBS within their networks. Mostad, (2002) says that Telenor has adopted LBS that focus on security and transport instead of traditional “where can I find”-LBS. Mostad’s view is concurrent with Telenor employee Bjøntegård (2003), who informs that Kompis, Telenor's only “where can I find”-service may be dropped within the year of 2003. For LBS directed to private mass markets, one has to turn too NetCom’s service portfolio. NetCom has services such as finding friends and points of interest in a subscriber’s vicinity (Mostad, 2002).

In order to relate how the positioning technologies (that will be examined in chapter 5) support implementations of LBS, it is useful to describe categories of these. The categories explain LBS according to their functional demands and similarities. Normal groupings are reflected by Steinfield (2003), Durlacher et al (2002), Swedberg (2001) Kar and Bowman (2001), but categories differ from article to article. Choosing which categories to focus in this thesis was done on the basis of existing LBS in the Norwegian market, which were categorized in line with the most common groupings. The focus in this thesis is within the following categories:

1. Information services
2. Safety
3. Fleet steering
4. Navigation
5. Asset tracking
6. Geographic routing of calls

I have deliberately decided to exclude LBS that are part of telematics (deciding calling costs dependent on a subscribers position - location based charging, finding best base transceiver stations (BTS) etc.) The six chosen categories each have many examples of LBS, but the following description only includes LBS analyzed as part of the case study in the Norwegian market. Examples of LBS available in the Norwegian telecommunication market in 2003, are as follows:

4.5.1 Information services – "Where can I find?":

There is a wide range of information relevant to persons with high mobility such as mobile phone subscribers. Location based weather forecasts, tourist attractions, landmarks, restaurants, gas stations, repair shops, ATM locations, theatres, public transportation are normal examples (Steinfield, 2003)(Swedberg, 2001). The general idea behind location based information services is to filter information according to the subscriber's position.

Spatial mobility causes mobile subscribers to find themselves in multiple contexts during a normal day. Although the mobile phone has made subscribers' lives more contextually mobile as some activities can be done in several contexts and places, there is a need to discover place with meaningful surroundings while moving around in space. When activities are less tied to specific context's and times, subscribers will need instantaneous access to information that is relevant to the activities and to the surrounding area. Such information is often at hand in an office, either in printed form, through the Internet or as local knowledge in a common area. When on the move subscribers need another way of getting to the same information and the new places themselves may also necessitate new types of information.

Location based information services offer subscribers a way of getting to information that is relevant to the surrounding area. These LBS therefore give a portion of the context for the place where subscribers are located. Location based information services can range from push based information about the occupied place to pull information where subscribers want to find something of relevance to a location. An example of the former is locally broadcasted information about restrictions for the use of mobile phones and thereby representations of practices for the area, while the latter can be inquiries of where to find the nearest restaurant based on a subscriber's current position. Push based information services has the potential of informing subscribers with practices for specific places based on positions. Such information can to some extent give notice to practices that traditionally has been mediated through architecture. If the LBS utilize positioning technologies that can sense a subscriber's proximity to certain areas without performing constant positioning, information about a place and the institutions it represents can be broadcasted to all the subscribers within the physical area that represents the place. If the positioning technology cannot sense proximity without doing constant updates of subscriber's positions and each update must be paid by the subscribers, the LBS is likely to be costly. Timeliness and accuracy is important for many push based information services. If the positioning technology is slow and inaccurate subscribers may receive information about places they have left or haven't been at all.

Pull based LBS are different in the way that they are invoked. Such LBS support subscribers that needs to structure their activity to the place they are located. By requesting information or functionality specific for the surrounding area, subscribers can find support for the activity they want to perform.
The underlying assumption is that the user knows what he wants to do, but needs to find out where to do the activity, or the whereabouts of the place he is looking for. LBS that are invoked by consumers in this way do not need constant updates with positioning information. A subscriber's position is found by the underlying positioning technology once it is needed for an LBS. When requested by subscribers, information that represents institutions is found when they are needed to perform an activity. Examples can be information about the nearest ATM when paying for something or the institutions of transport when traveling. Agre (2001) argues that since institutions are less tied to places and activities are more fluid, participants in an activity must negotiate the demands by several institutions. The solution might be to transfer the role of architecture to technologies, through devices such as mobile phones or ubiquitous computing. If activity is to be structured by information provided by an LBS instead of architecture, the information must be presented precisely, easily, correct and understandable.

The following LBS are the information services implemented in today's Norwegian market.

'I nærheten' (by NetCom):
Translated to English this LBS means 'In the surrounding area'. 'I nærheten' is a group of applications aimed at finding resources in the subscriber's surrounding area. The LBS consists of finding the nearest; ATM, bank, drug store, liquor store, place to eat and post office. Request and replies are SMS based, and you specify what to search for after the prefix 'Find'. The reply is a list with names of e.g. liquor stores with complicate addresses. Subscriber cost is NOK 6,- per positioning.

'Finn Taxi (by NetCom)'
Finding taxies can be done in the same manner as 'I Nærheten', with the difference that the returning information from the LBS is the phone number to the nearest taxi stop. A variant of the LBS is called 'Taxi direkte' (see chapter 4.3.6). This variant allows subscribers to call a number and get transferred to the nearest taxi stop automatically, without sending and receiving SMS.

'Vær' (by Netcom):
Location based weather information can be received by sending 'Finn Vær' to 1989. The LBS provides the subscribers with weather information (a forecast for the next 24 hours) for the area where the subscriber is located at the time of

request. There are multiple variants of the LBS where the subscriber can specify for example, a 9 day forecast, desired start time of the forecasts or manual input of where to get weather information from. The LBS can be accessed through WAP as well, and is NetCom's most successful LBS.

Information services and mobility

Finding information about objects or phenomena close to a consumer is interesting in the long run if the information picture changes with time. Causes of change range from the consumer's spatial movement with the following change in nearby objects, or that the nearby objects themselves change. Examples of the latter are when new ATM's, restaurants, drug stores etc are moved, removed or built. We see here that the context in the meaning of location based information services is the location of the resources the information services are to find. Changing a subscriber's location will typically change his context in this sense. This holds for weather forecasts as well, where a consumer will find that weather typically change from place to place and from time to time. In a hypothetic situation where the subscriber is stationary, weather updates are still interesting because of the change over time, and location as input parameter will still make interaction with the LBS easier for subscribers. Location based information services enable simple queries for nearby information and resources while being on the move, which in turn reduces temporal dependencies for when to access information.

4.5.2 Safety

A recent Ericsson Consumer Lab survey with 16,000 users in 8 different markets concluded that the most attractive LBS are safety services such as; emergency location, alarm notification (home break-ins, or car break-ins) and road-side assistance (Chen, 2002). Governments in many countries require that network operators shall provide automatic positioning of callers. Safety is a main driver for LBS (Schneider, 2000) and governments want to use a caller's position to enhance safety in emergency services (Steinfield, 2003). Safety can be found through institutions such as the police, hospitals, family and so on. As subscribers also act in places where these institutions are not represented physically or by architecture, a solution is to represent the institutions through services on mobile phones. Mobile phones enable contact between subscribers and institutions that represent safety. The subscriber's position is especially important and helps institutions find and assist people in distress. When a subscriber must provide positioning information manually when alerting safety-institutions, the results can be very varying in accuracy and correctness. Sometimes, the caller can also be unable to say where he is. By attaining positions automatically through positioning technologies, there is a possibility to represent the emergency area more precisely. Any accuracy of the positioning technology will help safety services in locating subscribers, but safety is improved by increasing the accuracy. LBS like "violence-alerting" take away the bonds between a subscriber's safety and their homes (architecture). The possibility of alerting the

Police through mobile phones lets subscribers bring institutions of safety wherever they move. In line with Agre's (2001) vision, this is an example of how an institution can be represented through a *"context aware digital device"* instead of through architecture. The activity of guarding violence-exposed subscribers is given by enabling contact with institutions through mobile phones.

Common for the safety services is that they benefit from the highest possible accuracy in positions, and at the same time gets value from positions of low accuracy rather than no positions at all. Governments have pushed accuracy demands for positioning technologies supporting safety services (Federal Communication Commission, 2003), which has accelerated development of positioning technologies for mobile phones. Safety services do not need constant updates of positioning information as a subscriber's position is only interesting in case of emergency, in other words at the moment when the alert is given. The usage costs of this LBS is not decisive as safety is highly valued, but there are moral and legal issues (Ministry of Transport and Communications, 2003) to how much network operators can charge for positions used in emergency services. The positioning technologies supporting location based safety services must perform in all types of topographical areas with GSM coverage. A solution to an all-embracing positioning technology is combining several positioning technologies and using the one that is optimal according to how it performs to the current topography.

Emergency calls:
The US E911 has been very focused on safety, and as mentioned in the introduction; safety is an important argument for Norwegian network operators as well. This and the fact that the Ministry of Transport and Communications (2003) has demanded free positioning of emergency calls as part of the concession agreements to build UMTS networks are important reasons for network operators to implement automatic positioning of all emergency calls. Such has been done since the start of 2003 (Telenor, 2003). When calling the 112 emergency numbers in Norway from a mobile phone, the position of the caller is recorded and presented on a map available to dispatch personnel. The technology supporting this LBS has low accuracy (a technology called CGI+TA that will be explained in chapter 5.3.2), but according to Telenor (2003) it satisfies accuracy demands specified by governments. One problem with this LBS is that it is developed by Telenor, and because of contest to capture the market, do not support subscribers with non-Telenor subscriptions. Colibria said that similar lack of roaming with positioning data was inhibiting adoption in their Kompis service.

Violence-alerting:
In 2002, the Norwegian justice department took initiative to offer violence-threatened persons a way of alerting the police in situations of danger. A cooperation between Telenor and the Police was completed in the summer of 2003, where commercially available equipment has been put together to form an operational service (Svendsen, 2003). The LBS is offered through a mobile phone

especially tailored with a red button and a GPS receiver. By pushing the red button, an alert is sent over the mobile network to the Police's operational central along with an SMS with information of the person's whereabouts. A direct line for voice communication with the police is also started automatically. This LBS is support by both the GSM positioning in Telenor's network (CGI+TA) and the Global Positioning System (GPS). Since the two technologies have different and complementing attributes, they are used in different situations.

Safety services and mobility
Safety services bring the safety of law enforcement and emergency assistance into all spatial areas with GSM coverage. This makes subscribers feel safe even in places that traditionally represent little assistance when danger arises, thus making the institutions of safety contextually mobile. The difference between a location based safety service from a normal safety service is that the subscriber's position is attained automatically by the LBS. This is especially help ful in situations where subscribers are unable to inform emergency personnel about their whereabouts because of lacking knowledge of where they are or physical hindrances from attackers. Interaction between emergency personnel and subscribers can in this way be released from information about location while the LBS still utilizes the position of a consumer when aiding a consumer in distress.

4.5.3 Fleet steering

Applications within fleet steering offer positioning of vehicles so that transport companies at any given time know where a vehicle is. Fleet steering simplifies transport companies' administration of transport vehicles and should not be confused with navigation services. There exist many fleet steering systems, used by for example train and taxi companies and the police. This study has only focused Telenor's fleet steering, a system that uses positioning of mobile phones to locate transport vehicles. Transport vehicles have a high degree of spatial movement and the vehicle's context also changes often. Examples of contextual mobility for vehicles are; how much cargo the truck is carrying, where it is located relatively to customers and how long the driver has been at work that day. By attaining some or all of these contextual cues, the fleet can be steered more effectively. Represented in a system, contextual information makes it is easier to decide the nearest truck for an assignment, to check if the truck has room for more cargo and where cargo is located at any given time. Findings from the case study conducted in Kakihara and Sørensen (2002), are directly transferable to the location based fleet steering service offered by Telenor. The fleet steering service offers real time truck location from automatic detection of trucks' locations based on positions that only take about 15 seconds to update. Real time truck location makes it easier to coordinate vehicles flexibly with basis on their spatial movements. Temporal mobility is supported through timely information and makes it possible to perform multiple tasks at once for vehicles. The automated sharing of vehicle locations reduces communication need between dispatchers and drivers while still increasing contextual information.

A limitation in Telenor's fleet steering is that the only contextual information given by the application is positions. A truck's position is represented on maps accessible to the dispatchers. However, positioning information is not matched with other contextual information such as the truck's cargo load, its assignments or the driver's current route (Telenor, 2003). If such information was represented in the location based fleet steering, the dispatchers would have more and better information to base their choices on. The resulting contextual image of the fleet could therefore enable enhanced fleet steering.

The practices belonging to the institution of transport companies can be mediated through a system where decisive information is represented. A normal practice in transport companies is to assign jobs so that the nearest truck is chosen while making sure that a delivery is close to other assignments for that truck. When attaining a truck's position with the help of an LBS and using the information to decide fleet steering, the activities of an institution is in fact supported by place. In contrast to Agre's (2001) framework, the activity is not formed by a place represented in architecture. The place is represented by pick-up and drop-off locations and a truck's relative positions to these, and decides how to arrange the activity.

The transport companies have everything from local assignments inside city centers to long distance deliveries where trucks have to cross remote areas. Location based fleet steering thus requires positioning in a wide variety of topographical areas. The performance demands to accuracy within each of these topographical areas will be discussed further in chapter 6.3.2.

As with safety services, increased accuracy of positioning is beneficial but in most cases not a necessity. As there is frequent positioning in location based fleet steering services, bulk prices of positioning has been applied. Implementations of the LBS can therefore use updated positions without massive cost.

Fleet steering (by Telenor):

Fleet steering is an LBS that offers surveillance of vehicles based on today's GSM positioning technologies. The vehicles are tracked by positioning of mobile phones and an operator gets the information presented on maps. Through this application, transporters can get an overview of their vehicles and are able to direct the fleet in an optimal way. The implementation is accessible on any Internet browser. (TietoEnator AS, 2003). Current solutions can provide drivers with route description and support data communication between dispatchers and drivers through SMS. Fleet steering is one of Telenor's most important LBS, and has a great market potential as there are 80-90.000 transport vehicles in Norway and only 2% of them use LBS (Telenor, 2003).

4.5.4 Navigation

LBS can be used to help subscribers choose the best routes to places. GPS navigation systems in cars is the most common appliance of navigation services and serves as a good example even though this thesis focuses on services offered on mobile phones. When used for navigation, LBS can support any activity that is connected to finding a place. The LBS will not structure the activity with significant institutional influence. Location based navigation rather helps activities that are related to other institutions. Practices for navigation will influence the way a navigation service is implemented, but most importantly practices may be changed as a result of having navigational assistance available at “all” times. Existing applications that support navigation has shown the need for high accuracy in the positioning. An LBS that gives navigational assistance with a 500 meter error margin will fail in usefulness for most subscribers. Implementations of location based navigation services may be dependent of the costs per position. For an LBS that is supposed to give constant, updated information about routes based on changing positions rather than on-request information based on the current position, positions must be cheaper. For the on-request type information where a subscriber wants instructions on how to reach a specific place, LBS have a concrete value to the subscriber. The value argument along with fewer positions makes the cost of each position less decisive for implementations. Navigation services need high accuracy in any type of topography.

1881 (by Telenor):
The voiced based number information service will provide personal navigation for the private mass market. A test project is started where callers who do not where they are can be positioned by 1881. The service operator gets the callers position on a map and can help them find the places they are looking for. Manual identification of visible land marks by callers is intended to help provide accuracy to the positioning, and navigation descriptions are provided through voice.

A high degree of spatial mobility makes it harder for subscribers to interpret their own contexts because it is shifting rapidly. Knowing how the surrounding area is organized is difficult when shifting from one area to another, unless the person is familiar and has extensive local knowledge. Navigation services are mostly concerned with positions, but in order to guide someone from a starting point to a destination, contextual information about the area must be addressed. When making use of maps to represent a subscribers position, the place is to some degree represented by geographical references in the map along with information about other objects in that same area. Contextual mobility is an effect of mobile technologies, but navigation itself is not meant to increase contextual mobility. The purpose of navigation is to assist subscribers with direction finding based on the surrounding area. Mobile phones support temporal mobility in that activities are less tied to certain places and therefore can be done at several times. Activities are not completely freed from temporality because of mobile phones, as there are many other variables that decides the time for when an activity must take place. Temporal support in navigation services is indirect because they support subscribers in situations that become difficult with increased spatial and contextual mobility, such as finding a route. Although I argue that temporal support is indirect, the mobility of navigational information with “constant” access loosens the bonds between activities and times for when information is available.

4.5.5 Asset Tracking

Asset tracking involves finding the locations of subscribers, pets, objects and vehicles. Finding subscribers can have great value, for example safety of children (Scheeres, 2002), finding employees (Batista, 2002) or in games (Strout, 2002). Retrieving stolen property like cars and boats is also possible with asset tracking. By equipping assets with normal or specialized mobile GSM terminals, they can be tracked by applications exploiting the mobile network.
Asset tracking supports institutions of social relations and ownership. The location based asset tracking uses an asset’s location to provide contextual information. By locating friends through LBS the practices of social relations can become dependent on places. Instead of making appointments in advance, subscribers may contact friends that are in proximity to themselves. Using asset tracking to retrieve stolen properties changes the way subscribers act in case of theft. A very accurate positioning is not necessary for asset tracking as low-accuracy solutions still give subscribers assistance for their activities. However, as with most other LBS, increased accuracy would be beneficial and enable implementations with much more detailed information about locations. In a situation where asset tracking is used to position a stolen car, cost of the position is not decisive if prices are around NOK 5,-. When used for deciding many friends’ whereabouts, the price per position will matter much more. If a subscriber has to pay NOK 50,- to locate the nearest among 10 friends, this may be intolerable. The topography of the areas where asset tracking should be used is very varying. Sometimes assets are located within cities with many buildings and reflection (urban areas) and other times they are in remote locations with little interference but less telecommunication infrastructure (rural areas). The positioning technologies that provides positions to location based asset tracking must therefore be able to perform under many topographical conditions. As will be discussed later, current positioning technologies perform poorer in rural areas and therefore affect LBS dependently on the implementation. The meaning of a position can also change according to the environment. Examples from friend finders (Colibria, 2003) shows that a position in rural areas with 500m accuracy can be just as informative and useful as a position in urban areas with 50m accuracy.

The location based asset tracking services available through Telenor and Netcom in 2003 are:

Find stolen property (by Telenor):
Subscribers can put specially tailored GSM devices, with battery capacity of two years, in property like boats and cars. The LBS is offered by Falken and subscribers pay subscription fees for the service. If the property is stolen, locating is done by Falken within 24 hours (Falken, 2003) (Telenor, 2003).

'Kompis' (by Telenor):
This is an LBS offered by Telenor, and is based on the 'Friend Finder' application developed by Colibria. The service's main function is to let subscribers organize friends on their mobile phones, and finding out where they are located. This LBS can be compared to traditional Instant Messenger like MSN Messenger, Yahoo Messenger and IRQ. Such messengers feature moods describing the state of the subscribers. Normal moods are "Away", "Busy" or "At work" etc. With 'Kompis', these moods are replaced by information about the subscriber's location, and the LBS can be accessed through SMS, WAP or Web. Additional functionality is sending group SMS messages and a world wide web based Instant Messaging. Cost of use for subscribers is NOK 5,- per position.

'Buddy' (by Netcom):
Buddy is NetCom's equivalent of Kompis. Costs are NOK 1,- to send messages and NOK 3,- to receive. When positioning many friends at a time, a small group discount is given (NetCom, 2003). The LBS is offered on SMS and WAP interface. The WAP interface will include maps by the end of 2003.

Asset tracking and mobility
Because of high spatial mobility of assets like subscribers and vehicles, there is a need to know where things are located in space. Assets not within the reach of a person's vicinity are often hard to find, especially if they are moving in unknown patterns. Asset tracking is mainly concerned with asset's spatial positions, but as with navigation services, matching a position with contextual parameters such as maps can be useful for illustrating and giving meaning to positions. For friend finders, increased contextual information supplementing position, about subscribers would be beneficial (Colibria, 2003). Mobile technology has increased contextual mobility and taken away many of the ways of capturing another person's contexts as interaction is done across context and without actors' physical appearance. Today's fiend finders give subscribers a notion of other subscribers' contexts through position, but additional contextual information could be useful in future versions. An implementation that developers are evaluating is to capture the situation of a person in similar ways that web based messenger do today. Contextual information can range from statuses like "busy" and "at work" to moods of the kind "happy" and "in need of someone to talk to".

Temporal mobility is not central for tracking stolen properties, but in a daily situation where a person decides activities on the fly, as a result of increased temporal mobility, asset tracking can be helpful. An example is situations where a person suddenly has 30 minutes of spare time and decides to go for a quick coffee. By using a friend finder this person can find the nearest friend and contact her to make an appointment.

4.5.6 Geographic routing of calls:

Connecting a caller to the nearest answering point has been used in wire-line network for a while. With Enhanced Call Routing, it is possible to route a mobile caller to the nearest answering point based on automatic detection of his position. In this solution it is amongst other possible to have one standard phone number to for example the Police and reaching the nearest station being up to mechanisms in the mobile network, based on the position of the mobile caller. Positioning is done while the caller is waiting for a line, and subscribers are therefore unaware that they are positioned.

A short analysis of geographic routing of calls using Agre's (2003) terms; architecture, institutions and practices may clarify the mapping between activity and place for this service type. Agre (2003) refers to architecture as the built environment and focuses on fixed structures. For the purpose of describing geographic routing of calls it is useful to see architecture as how institutions like the Police and Post offices are meant to cover geographical areas of a nation, a city, or even a neighborhood. It is a normal practice to route the call to the correct office when calling an institution. A typical example can be seen when calling the Police where a caller is routed to the office that is responsible for the caller's geographic area and thereafter routed to the police officer handling a case. Here we see that the activity is based on how a geographical area is organized (also called the place). Practice like the one described above can be transferred to callers with mobile phones when using location based geographic routing of calls. This type of LBS helps subscribers reach the correct offices based on their current positions in a way that eliminates much of the manual input both mobile subscribers and institutions have been forced to make.

Geographic routing of calls differs to some degree from the other LBS. First of all, the spatial mobility is not necessarily the reason for making use of geographic routing. Companies and authorities benefit from having only one common phone number for all departments and offices, as this makes it easier for subscribers to remember the phone number. To get the correct help, callers are gained with reaching the department or the office that is intended to cover the spatial area where the person is calling from. A reason for implementing location based geo-routing is that the penetration of mobile phones has assured that many calls come from non stationary phones, and other than traditional geo-routing mechanisms for finding the caller's area must be used. However, when first ensuring that geographic routing of calls from mobile phones can be done, new appliances can be useful as a result of the spatial, contextual and temporal mobility found in mobile subscribers. Completely new appliances are not taken into use yet, but NetCom is working on an implementation that illustrates the difference with mobile geographic routing from traditional wire line; routing a call to Oslo Taxi, directly to the nearest available taxi instead of a taxi station. This implementation assumes that increased spatial mobility changes the temporal and contextual needs when ordering a taxi. In this implementation, taxi drivers are not forced to go to a taxi station to get a fare and taxi dispatcher do not need to pinpoint taxies that are near the caller. Immediate routing to the nearest taxi can potentially ensure effective fleet steering for taxi companies and it gives subscribers increased immediacy and personal contact with the driver.

Typical examples of two different services with geographic routing of phones are:

Routing of calls to the Police (by NetCom and Telenor)

When dialing 02800, the caller is routed to the nearest Police office. This is done for all calls, and positioning with following routing of the call is done under connection without the subscriber noticing anything other than the normal ring tone (Telenor, 2003) (Netcom, 2003).

Taxi direkte (by NetCom):

Through cooperation between NetCom and Oslo Taxi, subscribers are offered an LBS that simplifies taxi ordering. By calling 920 00000, the subscriber is automatically positioned by the mobile network and transferred to the nearest Taxi. As a result of available accuracies, subscribers are offered 3 possible locations and must choose between them manually on basis of their own local knowledge. There is no specific pricing for positioning and subscribers pay ordinary connection fees.

Findings from case study regarding each service category can be found in table 2, and will be presented in further detail when discussed in chapter 6.

Service category	**Behavior in topography, accuracy and cost.**
Information services: -I Nærheten -Finn Taxi -Vær	-Topography: Possible to use anywhere but provide more useful information in urban areas (There are not many taxi stations, ATMs etc. in rural areas) -Accuracy: Subscribers are given several alternatives as a result of low accuracy -Cost: Seen as expensive and development with enhanced functionality is inhibited by price settings.
Safety: -Emergency Calls -Violence-alert	- Topography: Just as important in rural areas as they are in urban areas. -Accuracy: Need more accuracy in urban areas -Lacking accuracy necessitate more resources when trying to find subscribers. -Cost: Not a deciding issue, as safety is something subscribers are willing to pay for.
Fleet Steering: -Fleet Steering	- Topography: important in rural and urban areas - Accuracy: increased accuracy needed in urban areas. Lacking accuracy results makes the LBS less valuable when trying to find how long it will take for a vehicle to reach a destination. May necessitate contact with drivers to get exact information -Cost: Much positioning through constant use of the service, gets discount because of big volumes
Navigation: -1881	- Topography: Most relevant in urban areas, and use of the LBS is intended in these areas. - Accuracy: Need for high accuracy. Implementation is based on workarounds because of lacking accuracy -Cost: Not decisive, would not be used in situations where there is little need for navigational assistance
Asset Tracking: -Find stolen property -Kompis -Buddy	- Topography: relevant in all areas - Accuracy: helpful with increased accuracy, but still valuable with existing accuracy -Cost: For finding stolen property, costs of positioning is almost irrelevant compared to the higher values of the properties. For finding friends cost is decisive for how it is used.
Geographic routing of calls: -Routing of calls to the Police -Taxi Direkte	- Topography: relevant in all areas. - Accuracy: most implementations find enough accuracy in existing technologies. Routing of calls to nearest taxi is an example that would benefit from increased accuracy, and would eliminate need for extended interactions in the service -Cost: This is free of charge today, will probably change. Costs must be kept low.

Table 2: Service types along with their demands in regards to cost, topography and accuracy.

Chapter 5

5 Positioning Technologies

This chapter defines positioning technologies, explains technologies and relates them to theory. The three categories; network based, handset based and hybrid positioning technologies are presented. Finally the technologies used in the current Norwegian market are described.

5.1 Definition and explanations

As said in the introduction, positioning technologies find the location of a subscriber automatically and there are many variations of such technologies. This thesis is only interested in those relevant for positioning mobile phones and defines position technology for use in the study as:

> *"Positioning technology means technology based on radio signals, GPS or mechanisms in the mobile network, that allow an application to determine in real-time or near-real time the position of a mobile phone"*

Although positioning in this definition is concerned with finding a mobile phone, it also finds the person carrying the mobile phone or the object that contains the phone. In this way, positioning technologies find subscribers and objects such as cars or boats with mobile phones in them.

Positioning technologies are supporting mechanisms in the LBS, and should be seen as part of the mobile network. Positioning technologies have the role of finding a subscriber's or other objects' position, so that the location based application can do something with this positioning information. Applications usually take a position as input and provide content information or functionality based on the position, and thereby offers a service to subscribers as illustrated in in figure 8.

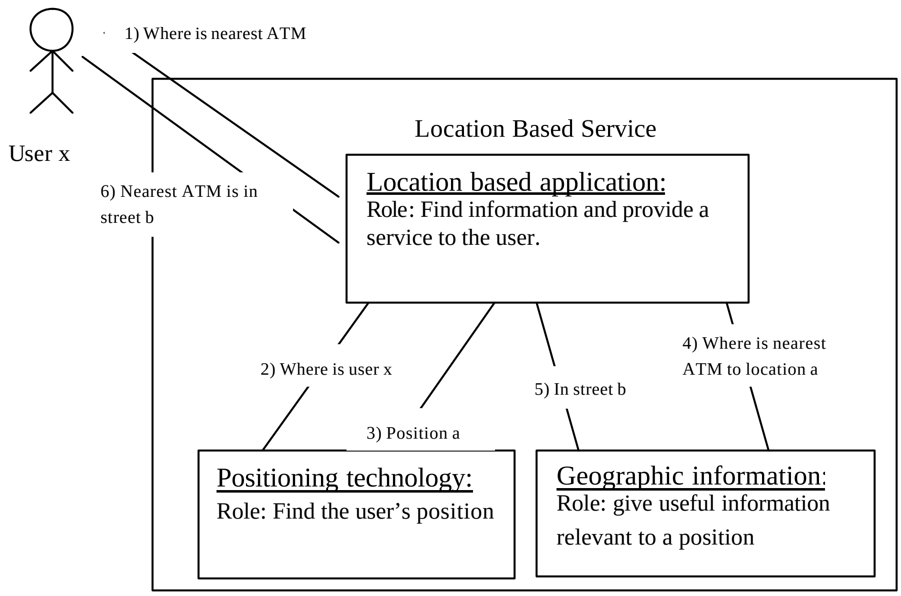

Figure 8: Abstracted illustration of how a location based service is supported by a location based application, positioning technologies and geographic information

The idea of focusing content based on contextual parameters, such as position, is not new. Focusing content of wire-line e-commerce applications based on manual input from subscribers has been done for a while. Normal input is often on the form of an address or a postal code. The modern thought, found in LBS, is that the position should be determined automatically without the subscriber having to provide it explicitly. There are many technical solutions for providing position within the mobile network automatically. Although standards have long been the way of the telecom business, choosing a standard positioning technology may inhibit development of other superior solutions. One of the functional requirements of the 3GPP ensures that this is avoided:

> "*Multiple positioning methods should be supported in the different Access Networks, including (but not limited to) UL-TOA, E-OTD, IPDL-OTDOA, Network Assisted GPS and the methods using cell site or sector information and Timing Advance or Round Trip Time measurements*" (Wohlert, 2001 p. 17).

Making use of current technology like mobile terminals and existing mobile network, whilst adapting for future demands and developments has led network operators to abstract the various technologies from the LBS applications. The normal infrastructure is built upon a Mobile Positioning Center that uses the underlying positioning technologies and mediates information from these to the LBS clients (Smith et al, 2001). The underlying technical solutions are based on different ways of achieving a position, but there are two normal categories; network based and handset based location technologies. This chapter explains the categories, and fold out the most important technologies within each category, lastly comparing them to each other as they have different and often overlapping

attributes. Solutions within the different categories vary in positioning accuracy and change imposed on the technical infrastructure.
As European drivers for LBS are commercial aspects, network operators naturally want to provide as good positioning as possible with as little cost as possible.

5.2 Space and place in positioning technologies

Most of the positioning technologies are meant to capture a position which is a representation of an area in space. A normal way of presenting a position is therefore through coordinates. Positioning technologies are needed because of the spatial mobility of mobile phone subscribers, and these positioning technologies try to capture physical positions (see chapter 6.1.1). Positioning technologies provide positions and do not put any meaning to the positions - a task left to location based application or the subscribers receiving position information. There are exceptions where the positioning technologies tries to capture a subscriber's location in a place, for example sensors that position a consumer on the philosophy of the consumer is here, lets do something. Sensors used for this purpose, capture a consumer's location and are not concerned with where the position is in space, but that the consumer is within reach of the sensor. The place - the context of the area or the appropriate behavior, is given through the application that uses a positioning technology based on sensing. These technologies are useful in LBS such as a phones access to menus of nearby vending machines or access to mobile payment based on proximity to the machines. Differences between various types of output generated by positioning technologies are given in chapter 6.1.1 under discussions around physical versus proximate positions and absolute versus relative positions.

5.3 Network based position technology

The position of a mobile phone can be determined by the mobile network. There are several techniques that involve different ways of calculating the position, each representing its advantages and disadvantages. Common parameters are accuracy of the position, network cost in data traffic and the amount of time a calculation takes. None of the network based technologies impose any changes to hardware in the mobile phones, thus keeping the price of the mobile phones lower although some positioning technologies demand change in the phone's software. Actual costs for the subscribers may still be higher when using a network based positioning technology. In a scenario when the price of getting each position is too high, it does not take long to reach the same expenses as represented by a one-time investment in new handset provided that handset based technologies would have a lower price pr position and higher investment costs. Figure 9 illustrates possible long term effects for subscribers in this scenario.

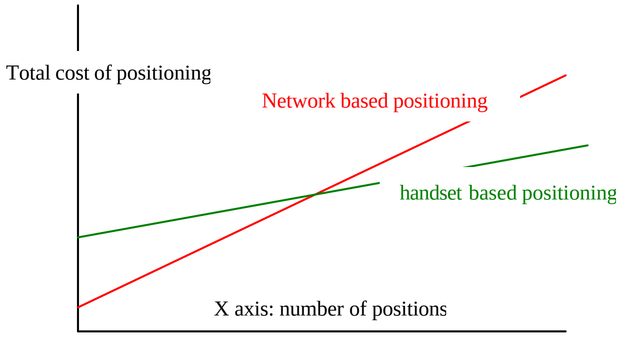

Figure 9: Total costs of network based positioning surpass handset based positioning in the long run if the price per position is higher for network based positioning.

Network based technologies have a great advantage in that they enable all existing GSM mobile phone owners to be potential users of LBS, as the network operator can locate any phone on the mobile network. This eliminates the subscribers need for investments in new technology, and it easier to become subscribers of LBS. For some technical solutions, change in the mobile handset's software is needed, but this is less costly than new hardware. Since the mobile phone subscribers cannot completely control when his or her handset are to be located, the network based technology are theoretically more imposing on subscriber privacy than handset based technology (Zandiri, 2001). The network based position systems use existing antennas so as to determine a position, and the existing mobile network to communicate the data. A mobile handset can be located whenever it is within coverage of the mobile network, and thus position inside buildings can be done as well.

In order to adapt for future demands, most network operators have separated the positioning technologies from the application giving an LBS. The common architecture consists of a Mobile Location Centre (MLC) which mediates between the mobile network and the location service client. The MLC retrieves data from the positioning system, calculates positions and convert the information to information that the location services client can use (Smith, Kealy and Williamson, 2001 p. 5). When separating the positioning technologies from the location based application, location based applications can be launched independently of which technology the mobile network uses for positioning. As described in chapter 5.6.1 and 5.6.2, Telenor has decided to use Ericsson's Positioning Server that takes care of separation between application and positioning technologies, while Netcom has implemented their own solution that does the same. A legacy problem where old applications cannot make use of new and more precise positioning technologies is avoided. The most common network based technologies are:

5.3.1 CGI - Cell Global Identity

Name:	CGI
Approach	Uses location of base station handling the call.
Strengths Weaknesses	Available now. No Change to Hardware or Software in handsets. Cheap technology Low accuracy. Less Privacy for subscribers.

Table 3: Significances of CGI

The simplest positioning technique is based on the geographical unit represented by the cell in which a mobile phone is connected. Each cell is centered around a base station with a radio antenna, and the technique locates a subscriber by the fact that he is within its coverage area. These cells are directional and represented by sectors (see figure 10). The whole mobile network is built upon a mosaic of the overlapping radio cells that can be uniquely identified by their cell ID. The size of the geographical area covered by a cell varies with concentration of subscriber traffic. (Siemens, 2001), and so does accuracy of the position. Since the Cell Global Identity is the concatenation of the Location Area Identity and the Cell Identity of the GSM network (Empirical Companion), no modification to the mobile network or the mobile terminal is needed to extract this kind of location information and thus is a very cost efficient technology (Nokia, 2003). As the technology only requires one base station to find a position, and there is no need for exchanging information between several base stations, less traffic is induced on the mobile network. Inside centers of larger cities, the cell coverage of each cell is small and the amount of cells is large. In such areas it is possible to locate a mobile phone with accuracy of approximately 300 meters when using CGI as position technology. However, in dense populated areas each cell covers an area of up to 35 kilometers, resulting in much poorer accuracy (Siemens 2001, p. 4).

Accuracy	300m urban up to 3km in rural. Dependent on cell density. Field tests by Laitinen et al (2001) showed: 328 m at 67% in urban and 639 in suburban
Precision	Good
Coverage Area	Very Good
Cost	Low
Physical/symbolic location	Physical
Recognition	Yes
Localized location computation	No

Table 4: Performance e valuation of CGI

5.3.2 Enhanced Cell-ID/CGI + TA

Name:	CGI+TA
Approach:	Uses location of base station handling the call + calculating distance from the BTS. Accuracy can be increased by directional antennas.
Strengths:	Available now. No Change to Hardware or Software in handsets. Cheap technology. Better accuracy than CGI
Weaknesses:	Relatively low accuracy. Less Privacy for subscribers.

Table 5: Significances of CGI+TA

A solution developed in order to enhance the relatively poor accuracy of CGI based techniques, is to combine the CGI with a timing advance variable. This variable is calculated by means of a synchronization signal used to get Time Division Multiple Access (TDMA) schemes to work. In order to synchronize time frames from each mobile connected to one cell, the mobile network determines distance between the base station and the mobile handset by comparing the access delay between the beginning of a time slot and the arrival of bursts from the mobile terminal (Swedberg, 1999). The access delay is proportional to the distance between the mobile terminal and the base station. Simplified, the TA can be used to determine the distance between a subscriber and a radio mast. By using this distance (TA) a more accurate position can be found, giving an area of about 100 and 200 meters (Knardahl 2001, p21). The accuracy varies with the size of the cells, which can be from 100m to 3500m. The width of the arc represented by each TA value is 550 meters, and represents the shape of a donut with the base station as center as can be seen in figure 10. Even though the arc correspond to a subscribers position, test results from referenced in Swedberg (1999, p 217) indicate an accuracy of about 100-200 meters.

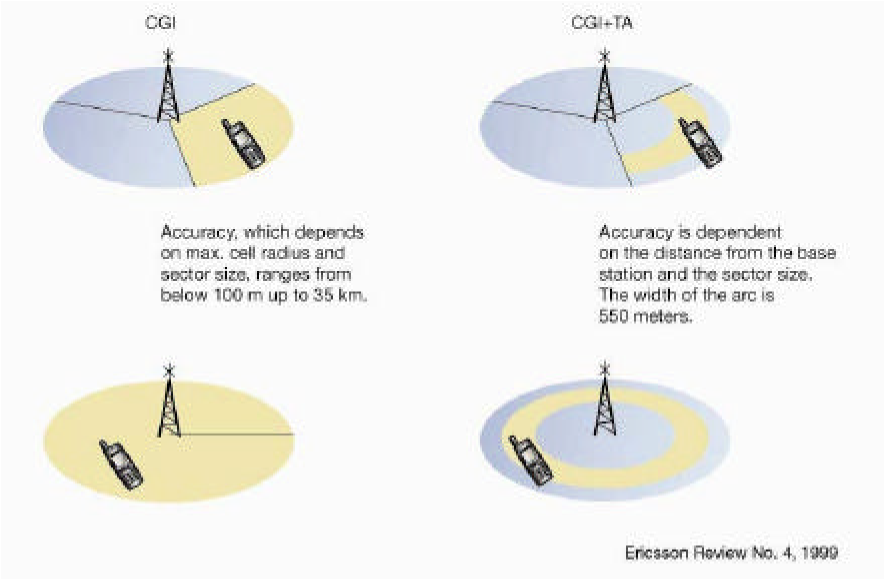

Figure 10: Illustration of increased accuracy with TA (Swedberg, 1999)

Other sources, like Cederquist (2002) provide a less optimistic accuracy. They project accuracy from 200 – 300 meters in urban areas, and up to several kilometers in rural areas because of the dependency between cell size and accuracy. Rural areas contain fewer subscribers and thus fewer cells can be used to cover larger areas, as one cell only can serve 8 subscribers at a time. As with the CGI positioning technology, no changes to the mobile network or the mobile terminal is needed. If the timing advance technology does not work, the system can use CGI as a fallback. In the next generation mobile network (3G, UMTS), Cell ID + RTT (Round Trip Time) will be the equivalent of CGI + TA (Cederquist, 2002).

Accuracy	100-200m (Swedberg, 2001) Field tests by Laitinen et al (2001) showed: 283 m at 67% in urban and 415 in suburban.
Precision	Good
Coverage Area	Very Good
Cost	Low
Physical/symbolic location	Physical
Recognition	Yes
Localized location computation	No

Table 6: Performance evaluation of CGI+TA

5.3.3 UL-TOA – Uplink time of arrival

Name	UL-TOA
Approach	Triangulation of position using signals sent from handset to at least three different cells
Strengths	-Better accuracy than CGI and CGI+TA. -No Change to hardware or software in handsets. -Can support calculation of speed of a moving subscriber.
Weaknesses	-Dependent of geography. -Needs visibility to LMU sites -New equipment (LMU and MPC) at BTS. -Less Privacy for subscribers. -Expensive, E-OTD is cheaper.

Table 7: Significances of UL-TOA

Uplink time of arrival (UL-TOA), also called Time Difference Of Arrival (TDOA) is a triangulation technology and requires three or more base stations to locate a mobile terminal (Chen, 2002). This technology is similar to Enhanced Observed Time Difference (E-OTD, discussed in chapter 5.3.1) in its use of differences between signals arriving at different base stations to calculate the position of a mobile handset (Empirical Companion). Time Of Arrival (TOA) is defined to be the start point of a time slot, and the uplink time of arrival positioning technology measures the TOA of the signal from a mobile terminal to four or more measurements units (Swedberg, 1999). The technique uses Location Measurement Units (LMU) at the base stations to measure the uplink time of arrival from the handsets and hands the values over to a mobile positioning centre (MPC). The MPC then calculates the time difference of arrival (TOA) between the different LMUs by subtracting pairs of uplink time of arrival values (Swedberg, 1999). On basis of the time difference of arrival between the different LMUs, the position of the mobile terminal is found and the MPC delivers a position to the application that required the location of the mobile terminal (i.e. the friend finder application). The accuracy of this position is dependent on the number of LMUs available and the geography of the environment, but is found to be 50m to 150m in urban settings (Swedberg 1999, p.217 and Chen, 2002). Since all calculations are done on servers and not on the mobile terminal, all existing mobile terminals can be located without change in the handset or addition to software in the SIM (Mountain and Raper, 2001 p. 5). Even though there are no changes in the terminal when using UL-TOA position techniques, the mobile network must support the LMU and the MPC.

Chen (2002) argues that this technique is expensive to deploy because it necessitates Location Measurement Units at each base station and Position Calculation functions on Mobile Location Center. “TOA (Time Of Arrival) technology requires larger network modifications and is therefore not very cost-effective. Rolling out TOA for an entire network is estimated to cost as much as 10 times the price of an E-OTD system" (Muller-Veerse, 2001, p. 34).

Accuracy	50-150 in urban areas. Field trials (Ericsson, 1998) show: -Bad urban (67%): 500m using 3 measurement units (reduced to 230m when using 7 measurement units) -Best urban results (67%): 38m using 7 LMUs -Worst rural (67%): 221m
Precision Coverage Area	Depending on chosen accuracy level. Medium, depending on amount of LMUs
Cost	Very high
Physical/symbolic location	Physical
Recognition	Yes
Localized location computation	No

Table 8: Performance evaluation of UL-TOA

5.3.4 Types of positions

CGI, CGI+TA and UL-TOA yield positions that are relative to cells in the mobile network, but the output is absolute and physical positions. This is achieved by comparing the relative position with the cell's absolute physical position, and thereby computing a mobile phone's physical position in space. All three network based technologies can therefore be used to broadcast functionality and information specific for a geographic area, although CGI is most appropriate for this purpose. Broadcasting information within areas can be done without going through the absolute position that is the standard output of these technologies. In such a way the positioning technologies can be implemented in a way that makes them supportive for discovering a place with specific behavior and meaning. This alternative way of conduct makes the technology similar to sensing technologies like Bluetooth (see below). An imagined situation is that an LBS senses all subscribers that are covered in a cell and broadcasts information about the place, such as; preferred behavior, possible services in the area or local historical information.

5.4 Handset based position technology

Handset based technology relates to positioning intelligence stored in the mobile terminal/handset or on the SIM card. In other words, the mobile terminal is used to do most of the position determination and the mobile network only plays a minor role. (Smith, Kealy and Williamson, 2001 p. 5). Unless network operators enters the handset industry and sponsors investments in hardware and software, subscribers will have to carry part of the costs in new positioning technologies. Although subscribers need new mobile terminals or/and new SIM cards in order to be a part of the mobile location service community, this may be cheaper with long term use if network operators choose to charge subscribers a lower price per position when using handset based technologies (as illustrated in figure 9).

5.4.1 Bluetooth

Name	Bluetooth
Approach	Detecting a Bluetooth device. Either detection of a handset or another device.
Strengths	High accuracy, No modifications to hardware in today's professional phones.
Waknesses	Expensive to build coverage areas of any size

Table 9: Significances of Bluetooth

Bluetooth is a "technical specification to standardize wireless transmission between a variety of devices such as PDA, mobile phones, laptop computers, printers etc" (mpirical companion). Because Bluetooth units sense other Bluetooth units so as to connect with them and perform some sort of communication, it can be seen as a sensing technology. In zones covered by Bluetooth devices it is possible to get a very exact position of the mobile terminal. These zones tend to be rather small as Bluetooth devices only have a reach of about 10m, making it hard to cover entire streets or other large areas (Steinfield, 2003 p. 6).

Apart from the advantage of giving an accurate position, this technology can be fully automatic by detecting a subscriber/mobile terminal when it is close to a relevant LBS or vice versa. Examples such as notification of nearby friends, vending machines sending out special offers to a passing terminal and receiving a floor plan when entering a shopping mall, all illustrate what LBS are possible out of recognition. It is possible to do this by network based positioning techniques as well, but it involves a much more complicated process (with the same demand for accuracy) of constantly checking a subscribers position and cross referencing it with possible LBS for that area.

Other advantages with the technology are that most new professional mobile terminals are equipped with a Bluetooth unit and that the unit is relatively inexpensive, ensuring lower prices for the terminals.

Manufacturers, however, struggle to expand battery life for mobile terminals to support the development and trends of mobile subscribers. Bigger screens with colors increase power consumption, so does the widened use of the phone as a result of SMS, MMS, E-Mail, games, calendars etc. found to be a part of the mobile terminal. Bluetooth units in the mobile terminals use a lot of battery as the unit constantly broadcasts radio signals. Although manufacturers are trying to decrease battery consumption (Mayor & Losi, 2001), it is hard to support a constant on functionality for it in the terminal when subscribers find their battery last for a shorter period. A realistic view is that the subscriber turns on the Bluetooth unit in the terminal when she wants to access LBS in her proximity. This solution to some degree breaks with the view that the process of being positioned should be done automatically without the subscribers input.

Proximity

There is no need for any change in the mobile network for supporting Bluetooth based location services, if used as proximity sensor (Steinfield, 2003). The term proximity denotes that it is the position of the mobile terminal relative to another Bluetooth enabled device that is of interest and not the terminal's physical position (article with proximity/physical). In this case, most of the software can be held at the Bluetooth enabled devices offering services, but for some LBS change to the mobile terminal's software is needed. An example where software is needed is in situations where the mobile phone is to be given access to user menus in other devices. There exist implementations of this type in today's market, that lets subscribers control certain programs on their computers over Bluetooth using their mobile phones. Despite not being used for commercial LBS yet, similar implementations of Bluetooth sensing technologies can be used for such purpose, for example controlling vending machines and similar.

Physical position

If Bluetooth is to be used as physical position detection and enable all kinds of mobile LBS, the beacons need to communicate with the mobile network, imposing change in the network. As of the short reach of Bluetooth, an extensive number of beacons would be needed, ending in solution that has a low economic feasibility.

Accuracy	10m.
Precision	?
Coverage Area	Very small
Cost Physical/symbolic location	Low (high if covering larger areas) Physical and symbolic
Recognition	No (can be implemented by the application)
Localized location computation	No (but not dependent on mobile network)

Table 10: Performance evaluation of Bluetooth

5.4.2 GPS – Global Positioning System

Name:	GPS
Approach:	Triangulation of position using signals from 4 satellites. GPS at LMU gives access to 4 available satellites.
Strengths:	-Very good accuracy. -More Privacy as subscribers are in control of when positioning takes place. -No change in mobile network.
Weaknesses:	-Dependent of geography needs free line of sight. -Not usable indoors. -New equipment (GPS at LMU). -Hardware change in handsets and in network -Increased price of handset -Increased size of handset -Increased battery consumption -Long warm up time, for getting connection with satellites.

Table 11: Significances of GPS

The positioning system with highest accuracy is Global Positioning System (GPS). The GPS system was originally designed for use by the US military, and it consists of 24 Navstar satellites in orbit around the earth. When launched for civilian use, an artificial error margin was installed in order to protect privacy. Today, there are two GPS systems, the European and the US. Both systems have removed the error margin, and hence accuracy can reach 4 – 10 meters (Siemens, 2001). In today's society, we can se a wide use of Standalone GPS units in many cars, boats and planes (Swedberg, 1999). The drawback is affected by extreme weather conditions such as storms, and requires an open line of sight to at least four satellites. This fact makes it weak for use in urban areas and indoor, which are the places where most of the mobile services are used (Mountain and Raper, 2001). The four satellites send signals with a time stamp and a description of the position of the satellite. By comparing the signals from four or more satellites, the GPS receiver can calculate its own position.

The position is calculated by the GPS receiver, but even if a mobile terminal would have a suitable transceiver, it would take more than 10 minutes to get the position. Other factors are that the GPS chip and antenna adds extra bulk to a mobile terminal, and increase power consumption. These are negative factors in a market where manufacturers are trying to make mobile terminals smaller and faster with longer battery life. Despite the mentioned issues attempts to place GPS in a mobile terminal have been made by both Benefon, who launched a range with map data stored on the terminal, and Ericsson when they launched their Communicator platform. None of these have made a good impact in the mobile phone market. (Mountain and Raper, 2001). Telenor (2003) has solutions where GPS is used for positioning and the mobile network only serves as an information bearer in mobile location services. These are services for fleet steering applications used by transport companies.

Performance:

Accuracy	4-10 meters
Precision	High
Coverage Area	Worldwide
Cost	High handset costs, free positioning
Physical/symbolic location	Physical
Recognition	No
Localized location computation	Yes

Table 12: Evaluation of GPS

5.4.3 A-GPS – Assisted Global Positioning System

Name:	A-GPS
Approach:	Triangulation of position using signals from 4 satellites. GPS at LMU gives access to 4 available satellites.
Strengths:	-Very good accuracy. -More Privacy as subscribers are in control of when positioning takes place. -Faster positioning than Standalone GPS. -Less battery consumption than Standalone GPS -Less bulk to handsets than Standalone GPS -Good coverage in rural areas.
Weaknesses:	-Dependent of geography needs free line of sight. Very bad coverage indoor. -New equipment (GPS at LMU). Hardware change in handsets and in network -Increased price of handset -More battery consumption than non GPS based solutions. More bulk than non GPS based solutions

Table 13: Significances of A-GPS

Because of the problems with GPS for mobile phones, researchers have developed the Assisted Global Positioning System, where some of the parameters are stored in advance through set GPS receivers installed in the mobile network. (Siemens, 2001) In this way the system does not have to search for all the 24 satellites and the other of the calculations are also done in advance, reducing the positioning time to a few seconds.

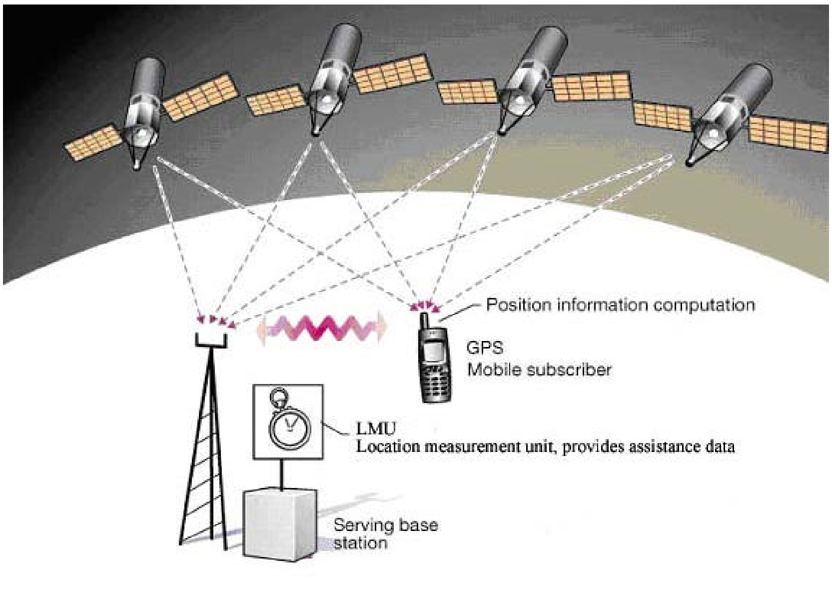

Figure 11: A-GPS uses four satellites and assistance data at the Serving base station. (Swedberg, 1999)

The way A-GPS works, is that the mobile network can assists the integrated GPS receivers with various information that give them better coverage than standalone solutions. LMU with GPS are used to gather assistance data, which is transmitted to the mobile terminal so as to give satellite ephemeris - a table with satellite information ensuring connection with the closest satellites and differential GPS correction - a way to compare GPS information from the network with GPS information from the terminal (Swedberg, 1999). In order to provide this information, a LMU must be set up every 300km in the network, providing accuracy within 10-20m. To improve coverage, Swedberg (1999) says that one LMU per third BTS is needed for a highly accurate time reference, which would improve indoor coverage. After integrating the functionality of GPS and the mobile network, a Mobile Positioning System (MPS) collects the differential GPS data from the receiver in the handset and transmits this over the mobile network making use of LBS possible (Kar and Bouwman, 2001).

The advantages with A-GPS are that the positioning is faster, with better coverage and less power consumption than a solution where the terminal carries the GPS receiver itself and a smaller required signal level (Lähteenmäki, 2000)(Cederquist, 2002). A-GPS is the technology that theoretically gives the best accuracy (France et al, 2001) and can give positions within 10 meters (Chen, 2002 and Swedberg, 1999).

Accuracy	5-30m (Openwave, 2002)
Precision	No available data
Coverage Area	High, but depending on GPS at LMU
Cost	High handset costs. Probably not free positioning as network operators need return from hardware investments.
Physical/symbolic location	Physical
Recognition	No
Localized location computation	Yes

Table 14: Performance evaluation of A-GPS

GPS and A-GPS utilize a GPS receiver's position relative to the known positions of satellites. The output of these technologies is always absolute and physical, on the form of coordinates. The technologies in themselves are only meant to capture positions in space, and on this level spatial mobility is relevant. A location based application that is enabled by GPS or A-GPS, must on the other hand be aware of contextual mobility. As explained, the applications compare positions with geographical information and thereby offer a portion of context and place for subscribers. Since the GPS based technologies do not support indoor positioning and the high accuracy are not needed for all LBS, it is important to consider contextual mobility of the potential users when taking use of these technologies to support LBS.

Different types of positioning technologies have varying attributes and performances in the same physical conditions, which should be considered when developing LBS. Enhanced Observed Time Difference (E-OTD), explained below, is similar to GPS enabled technologies in its relevance to spatial and contextual mobility, but it's nature and attributes make it support different situations and LBS than GPS.

5.5 Hybrid position technologies

Hybrid position techniques are a mix of handset based and network based technologies. There is often an interaction between the mobile terminal and the mobile network, each sharing information with the other to find the position. The hybrid technologies therefore require change in the handset as well as the network (Knardahl, 2001).

5.5.1 E-OTD - Enhanced Observed Time Difference

Name:	E-OTD
Approach:	Triangulation of position using signals from multiple BTS and software in handset
Strengths:	-Better accuracy than CGI and CGI+TA. -No Change to handset's hardware. --Can support calculation of speed of a moving subscriber. -Cheaper than UL-TOA
Weaknesses:	-Change in handset's software. -Network investments -Expensive (cheaper than UL-TOA) -Needs visibility of base stations for good performance.

Table 15: Significances of E-OTD

The Enhanced Observed Time Difference (E-OTD) positioning technology exploits signals from three base stations in order to find a mobile terminal (Cederquist, 2002). Signals that can be used are synchronization, normal and dummy bursts. (Swedberg 1999 p. 216). The technology uses the serving base station and at least two other nearby base stations to measure the observed time differences (OTD) (Siemens, 2001). The OTD is the time differences between arrival of bursts from nearby pairs of base stations and for a basis for calculating a position (Mpirical Companion). Measurements of the OTD are done in the mobile terminal, indicating E-OTD as a handset based position technology. New software is needed in the mobile terminal, in order to calculate the position. Additionally, the network needs Location Management Units consisting of GSM radio, a GPS receiver and a reference transmitted by a GPS satellite to support the E-OTD system. (Cederquist, 2002).

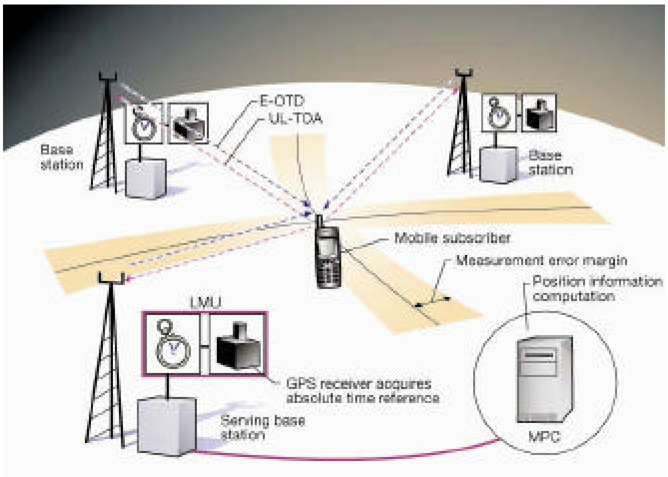

Figure 12: E-OTD; the terminal measures observed time differences from receiving base stations

As the transmission frames between various Base Transceiver Stations (BTS) are not synchronous, the network measures a Relative Time Difference (RTD). E-OTD needs three geographically distinct base stations, the network measurements of RTD and the handsets measurements of OTD. (Swedberg 1999 p. 216)

Since the position of the base stations is known, the position of the mobile terminal can be calculated either at the terminal - if the necessary information is available to it, or in the network (Siemens, 2001). Through these two opportunities, the terms 'handset-assisted' and 'network-assisted' explain the technology better than the common categories; handset based or network based. Swedberg (1999) argues that a network-assisted approach is used if the calculation is done in the terminal. In this option, the mobile terminal measures the OTD and computes its own position, whereas the network assists it with supplementary information such as BTS coordinates and RTD. If the measurement is done in the network, it is handset-assisted. In this scenario, the mobile terminal measures the OTD and sends the values to the network. The network then finds the position by comparing the OTD to the RTD and the BTS coordinates.

Various sources seem to have different views on how accurate E-OTD is. Swedberg (1999 p. 216) claims that accuracy is 60 meters in rural areas and 200 meters in bad urban areas, while Cederquist (2002) says that it varies from 50 to 250 meters. Siemens (2001 p. 5) provides the most opportunistic accuracy with 150m in bad conditions and down to just a few meters under ideal conditions. It is important to comment that these are theoretical accuracies, as E-OTD is not set to actual use and thereby not properly tested in a true environment.

In the next generation mobile network (3G, UMTS), OTDOA (Observed Time Difference of Arrival) will be the equivalent of E-OTD (Cederquist, 2002).

Accuracy	60-200m Field tests by CPS (in Laitinen et al, 2001) showed: 50m (67%) in suburban areas and 125m in urban areas.
Precision	?
Coverage Area	Medium, depending on amount of LMUs
Cost	High
Physical/symbolic location	Physical
Recognition	Yes
Localized location computation	Yes

Table 16: Performance valuation of E-OTD

5.6 Other Technologies

There is a range of positioning technologies offered by companies. I will not go in detail on all these technologies in this thesis, based on factors such as possible low market penetration, very high implementation costs, demand for unobstructed line of sight etc. Some examples of such technologies that will not be focused in the discussion on dependency between positioning technologies and service development are:

5.6.1 Angle of Arrival

As one BTS cover multip le cells, and the network knows which serving cell for each mobile terminal, a rough estimate of the angle of signal from the mobile terminal proximate to the BTS can be done. A mobile terminal tries to contact about six different cells or frequencies at all times. By combining information from these cells, one can find the common coverage area for all the cells, and thereby the position of a mobile terminal. (Knardahl 2001, p 21). The technology requires an array of antenna elements to determine the direction of the mobile signal, is good for tracking a continuous signal and has a good accuracy (said to be less than 125m)(Chen, 2001). The main drawback is that it is expensive to deploy. (Chen, 2001)

5.6.2 Signal attenuation

If the BTS' sending signal strength is known, it is possible to find distance between the BTS and the mobile terminal by applying predicted signal strength measurements. This technology requires a clear and unobstructed line of path (Knardahl, 2001).

5.6.3 Location Pattern Matching

When a signal from a mobile terminal travels through a city centre, it picks up noise from reflections and interference from buildings and architecture. By building databases with noise information for various locations in urban areas, this information can be used to find a mobile terminal's position. This is done by comparing the noise in the signal from the terminal to the database of multiple noise profiles for respective locations. If no matches are found, the system can make estimates of likely locations. The accuracy for the technology is low and dependent on many variables. It is resource demanding to build databases for all areas where mobile operators want to offer mobile LBS.

5.6.4 Netmonitor

Netmonitor is a technology where diagnostic software built into the mobile terminal monitor variables such as signal strength and nearest BTS. This information is compared to a database containing positions of BTS's giving current positions for the mobile terminal (Knardahl, 2001). The technique provides low accuracy and requires changes to the handset.

5.7 Standardization

There are no standardizations of what should be the minimum required positioning technology implemented by a mobile network operator in Europe. The question has been raised in ETSI (European Telecommunications Standards Institute) where it was posed that the operators could choose between UL-TOA or E-OTD (Wohlert, 1999). In the proposal by Wohlert (1999) it is argued that mandating a specific technology may be in the best interest of the companies producing the different technologies, but may not be so for the public or service providers. On the influence from possible discrimination of new advantageous technology and possible increased complexity of handsets for subscribers not interested in LBS, Wohlert recommends that all positioning technologies remain optional with no mandatory requirements. Three location technologies have, however - been standardized (should not be confused with mandatory) by ETSI. They are E-OTD, UL-TOA and A-GPS. (Smith, Kealy and Williamson, 2001)(ETSI, 2000)

The consequences of absent minimum demands for accuracy are that the development of positioning technologies and investments in such is driven by commercial aspects. This is exactly the picture in the Norwegian market, where operators want to see increased income from LBS, and let this be decisive for investments in positioning technologies (Telenor, 2003) (NetCom, 2003). Although the US FCC mandate has pushed development in positioning technologies, demands have represented heavy investments from network operators with daily fines if lagging behind (NetCom, 2003). Norwegian network operators are happy to be let of such demands and expenses. (Telenor, 2003) (NetCom, 2003)

5.8 Positioning technologies in today's Norwegian market

There are two network operators on the Norwegian market offering positioning through their infrastructures; NetCom and Telenor. Conversations with representatives from the two operators show some similarities with regards to the will to invest in positioning technologies, sophistication in today's technology, focus on future positioning technology investments (Helgesen, 2003 and Telenor, 2003). Neither of the two operators are making serious investments in new technologies. The reason is that they want to ensure return on investments, which can be illustrated by Brage Bjøntegård quote in ITavisen (2002):

> *"We have taken necessary investments to obtain a platform for positioning in the network. We now whish to test how users experience the services. We must document a need before we can make further network investments to improve the services (translated from Norwegian)"* (Mostad, 2002).

5.8.1 Positioning technologies in NetCom's network

NetCom uses Cell Global Identity, and do not use Timing Advance to enhance accuracy. They have developed their own way of enhancing accuracy, called position enhancement. This is a solution that is not part of a standard for positioning. By comparing the CGI with coverage maps provided from their radio planning tool, NetCom can compare actual signal strength with expected signal strength and get a more accurate fix. Comparison from several Base Stations is used to find a location, and accuracy is similar to CGI+TA technology. Experiences with the technology give positions within 75-100 meters in best-case scenarios, which is in urban areas. In areas with fewer base stations numbers can reach up to several kilometers in worst-case scenarios. (NetCom, 2003)

Middleware approaches are different from standards as well. Instead of using a positioning center like Ericsson MPS (used by Telenor), they have their own middleware-solution. One of the features for this middleware is that an anonymous SMS is sent to the terminal being positioned so as to force and update of the Cell ID, a process done with other signal in a standard MPS. Cell ID's are not normally updated when there is no traffic to a mobile terminal, and the system can therefore give a completely different location of a subscriber compared to where he is physically. This way they know that the terminal has a recent and updated cell ID, but there are downsides to this solution as well. The SMS may slow down response time for a position, but the whole positioning process, from a subscriber's request to receiving a position, takes less than 13 seconds for 80-90% of positions (NetCom, 2003). Both Telenor (2003) and Netcom (2003) argue that response time of the positioning technology is not a decisive issue for today's LBS

Updating CGI values is not always important, and is therefore excluded for positioning to LBS with lower accuracy demands (NetCom, 2003). An example of an LBS that uses the last known CGI is VÆR - a location based weather service that does not use position enhancement.

For the future, NetCom believes that A-GPS may be an important technology with its inferior accuracy, but this does not mean that they put less attention on their existing technology. If A-GPS is implemented it is dependent on a fall back technology with relatively high accuracy for situations where A-GPS does not perform (NetCom, 2003).

5.8.2 Positioning technologies in Telenor's network

Telenor uses Cell Global Identity with the combination of Timing Advance (CGI+TA). Positioning in their network is based on Ericsson's MPS, a solution that follows standards (ETSI?). Telenor is constantly trying to better accuracy of their existing technology by comparing outputs from positioning to data already generated in their network. Similarly to NetCom, they have found that accuracy can be enhanced by matching position with coverage maps generated from radio planning tools. Initial tries when combining CGI+TA with coverage maps has shown improvements of up to 70%.

There is also use of Fleet management services (Locus) that use GPS for positioning and the GSM network to transmit data from vehicles to the central and to compare positions with geographic information.

To Telenor's (2003) understanding Netcom has a quicker response time as they use mechanisms in the GSM standards to obtain CGI values. Response time may also get slower due to safety mechanisms applied before 3rd party developers get the information, to preventing misuse of positions. This increases a 2 second response to 5seconds and a 5 second response to 12 seconds (Telenor, 2003). These numbers show that NetCom and Telenor have similar response time in practice. Further, response time is no large problem as subscribers do not take notice of a delay of around 10-15 seconds, because the delay of sending an SMS or using WAP is longer. This shows that the response time of the information bearer is more critical than the positioning itself. An example where positioning is utilized and presented in a non-SMS based service, is geo routing of calls to the police where the caller is positioned and transferred to the nearest police station during the normal call setup time.

Capacity is much greater for Telenor than Netcom, because of the Ericsson MPS, and can handle 60 positions per second (Telenor, 2003). The robustness of today's positioning technologies is a result of the simple solutions; "positioning today is very basic, more like cutting peaces of cakes" (Telenor, 2003).

Telenor express that they eventually will need positioning technologies that increases accuracy and expands on the drawbacks of their existing technology. A-GPS is a technology with much higher accuracy than CGI+TA, and is believed to arrive on the Norwegian market in a couple of years (Telenor, 2003). The two technologies also represent different performances in specific topographical conditions (more on this in chapter 6).

UMTS will gradually take over for GSM in a long term period. This is taken into consideration when investing in new technology, and network operators want to ensure that investments are useful in the next generation network as well. UMTS has a positioning technology specified in its standards that is similar to CGI+TA, called Cell Id Round Trip Time – (CGI-RTT). It will be years before this technology can compete with today's GSM positioning because of the initial low density of base stations (Telenor, 2003). After two years, the amount of UMTS BTS' may start competing with GSM.

Bluetooth will probably take even longer to be in commercial use, and Telenor (2003) has evaluated Radio Eye as a possible indoor specific positioning technology.

Chapter 6

6 Analysis and Discussion

This chapter analyses LBS on the current market and discusses the LBS in regards to accuracy, topography and cost. Discussions include how the positioning technologies affect implementations of LBS. The way the discussion is build up is through key points found in the case study, exemplified with how this is manifested in LBS.

When comparing the characteristics of different positioning technologies, they show that each positioning technology have varying advantages and disadvantages. There is often a trade off between variables, i.e. increasing the positioning accuracy affects the mobile network with extra cost in traffic and demands higher investment costs in technology for either network operato rs, mobile subscribers or both. If operators choose a cheap technology with low-level accuracy, this may exclude some LBS that demand a high accuracy. As discussed in chapter 4, there is a huge difference in the demand for accuracy from LBS to LBS. Giving weather information based on a subscriber's location can tolerate accuracy less than a kilometer as weather does not usually differ from block to block. Directing a traveler to the nearest tram station on the contrary, requires a much finer accuracy as there is potentially several such within one block inside the center of a larger city.

6.1 Accuracy

"There is demand for higher accuracy in positioning technology in today's market" (NetCom, 2003). On the Norwegian service market, there are already LBS that need increased accuracy in the positioning. These are LBS that can be implemented on enhanced CGI, but they would fulfill their potential to a much higher degree with added accuracy from the positioning technologies (NetCom, 2003). The positioning technologies generally serve the task of finding a position in space, but when utilized by the LBS this position is transformed to a location (refer to table 2 in chapter 3) and is thereby given contextual meaning. It is the contextual meaning that is interesting for subscribers of LBS and it is this meaning that ultimately is supposed to support the activities of subscribers. When supporting subscribers' activities, it has been argued that the LBS may replace the functionality of architecture when mediating the practices of institutions (Chapter 4). The LBS should therefore provide information with sufficient accuracy, and must be able to match the accuracy previously represented by architecture. LBS in need of improved accuracy are navigation and fleet steering; as such implementations are affected by today's moderate accuracy. The lack of accuracy changes how the LBS is implemented by service providers and how it is used by subscribers. A good exemplification can be given through looking at the upcoming '1881' service, and the existing 'nearest taxi' service. (See chapter 4.3.1):

6.1.1 Increased accuracy by manual input – Workarounds in 1881

The voice based number information, 1881, will be equipped with a positioning system that locates callers, and service operators are presented this information on a map. The LBS enables subscribers with little or no local knowledge to be positioned independently of saying the name of their area. Callers are then directed towards their destination by descriptions from the operator. Since there will be accuracy between 200-500 meters inside city centers, land marks manually identified by subscribers during the call, are intended to aid in finding exact whereabouts of subscribers. If the subscribers are to identify nearby restaurants or names of places they have passed, this information must be put in the system and portrayed on maps along with callers positions. Use of the application is much more complicated and requires constant interchange of information between caller and service operator. If a positioning technology of better accuracy supported the navigation service, it would be more concise and fast, and require less from callers. Telenor (2003)

Context in 1881 Navigation using space and place

What this implementation in fact involves, is adding contextual information about the callers surrounding area. This requires that the caller partakes in the navigational process and that he or she must detect places in new and unfamiliar spatial areas. Traditional design of context-aware applications (Agre, 2001) tries to capture context automatically and give the subscribers value out of presenting information and functionality accordingly. The implementation in 1881 navigation attacks the problem of detecting context from the opposite angle. The callers receive valuable navigation-information because they provide information about the context so that 1881 operators can pinpoint them more accurately. Referring this to the theoretical basis in chapter 3, the implementation actually represents a way of detecting positions in space using information about the place – and not vice versa. Subscribers using 1881 navigation detect the place by means of what Agre (2001) calls architecture and not through institutions or practices. Optimally, an application that is intended to aid subscribers in how to act according to context, should require as little input from subscribers as possible. When realizing this goal, increased accuracy of positioning technologies is important if the LBS are to provide exact information to the subscribers.

6.1.2 Effects of lacking Accuracy – implementations of 'nearest taxi'

When calling 920 00 000, subscribers are positioned automatically and routed to correct taxi stations, or cars, based on their spatial position. The LBS matches a subscribers position against the positions of taxi stations, and contextual information is found. After being located, the subscriber is given three choices for nearby taxi stations by a voice machine. NetCom (2003) would prefer that the LBS could find higher accuracy in the positioning technology and thereby exclude any manual input from the subscriber. The situation today is that the system cannot give the correct nearest station in many cases, which necessitates explicit choices between possible nearest stations. The problem is not only that the LBS needs extra interactions between a subscriber and the system, but also that it is dependent of a subscriber's knowledge about the local area. Subscribers seldom know which one of three taxi stops is nearest when they are in an unfamiliar area or have little local knowledge. Further, choosing between options may represent a problem for subscribers who do not speak the language well enough to understand the choices and instructions offered by the automatic voice machine (NetCom, 2003). The basic idea of the LBS is that it is supposed to support subscribers that are not familiar with their surroundings, a situation often caused by contextual mobility. By using contextual input from subscribers this implementation fails to fulfill this goal. The situation is similar when accessing the LBS by SMS messages. Subscribers get three choices of nearby taxi stops in the replying SMS and must choose between them (NetCom, 2003).

6.1.3 Different accuracies

Lacking accuracy leads to a question of the various accuracies represented by different technologies support different types of LBS. Beinat (2001) provides a good example that illustrates how technology support different accuracy demands in LBS, illustrated in table 17:

Locating:	Technology:
What area of town What neighborhood	CGI CGI+TA
What street What street corner	E-OTD A-GPS, UMTS

Table 17: Accuracy demands as supported by technologies

Although Telenor only uses CGI+TA technology, the need for differentiated accuracy in LBS is still highly relevant. Some places, like cities, range over large spatial areas while others such as train stations or ATM's do not. For that reason the operator offers a way of providing differentiated accuracy and giving useful information that can be utilized in applications that match position with geographic information (Telenor, 2003). Telenor offers 3.party application developers different degrees of accuracy and output types. Positions can be given in the following forms:

-Cartesian products in the form of latitude, longitude.
-Postal code
-County number
-Place name

Instead of using positioning technologies with accuracy that is fitted to each of these situations, the granularity is achieved by referencing the position with geographic information, which again may increase response time. In this way, accuracy is not only dependent on the positioning technology used in the infrastructures, but also very much on how the information is portrayed. To transfer this to how subscribers perceive accuracy, it is useful to look at how positioning information is communicated through the LBS to subscribers. The Buddy service by NetCom illustrates how experienced accuracy is dependent on the way information is given.

6.1.4 Accuracy in presenting positions - experienced accuracy in Buddy

The Buddy service (described in chapter 6.3.5) is supported by WAP, SMS and WEB interfaces. Through use of the LBS on all interfaces in this study, experiences of accuracy were completely different on the different forms. The nature of the interfaces forces different representations of a subscriber's location. Through SMS, a location is typically given on the form:

"TG is located in the area of HOMANSBYEN (OSLO). This is approximately 2,4 km south of your position".

Table 18: Position information on an SMS interface

Apart from the reply only being of value if the subscriber knows where Homansbyen is, the accuracy of this reply is dependent on how large the area of Homansbyen is. In contrast, when accessing the LBS through web, position is given on a detailed map (see figure 13).

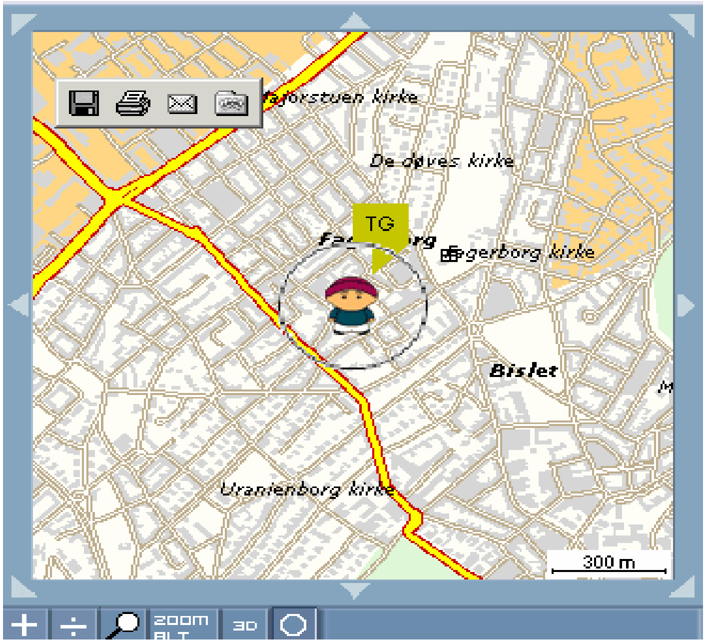

Figure 13: Position information on the web interface

Sometimes, the web implementation could give results where a friend was positioned in the correct house, and this output was always conceived as more accurate even though the position these were based on is them same for both interfaces. This view is shared by NetCom (2003), who also considers a map position much more informative. They have consequently chosen to provide better maps for their web interface. Further, the WAP interface that only provides the subscriber with a textual description akin to the SMS interface will include maps. The resolution of these maps will be personalized dependently on the display resolution of a subscriber's mobile phone (NetCom, 2003), and NetCom intend to utilize WAP-Push to make an implementation where subscribers can send maps to each other for describing directions etc.

The experience from Buddy's representation of positioning information is shared by NetCom. LBS rely on the quality of the geographic information such as maps and its connected points of interest, such as ATM machines. NetCom believes that geographic information of poor quality and few updates is one of the reasons why 'In vicinity' services are of little success (NetCom, 2003). Data accuracy is normally used to describe the level of detail of information and is important to consider in the provision of spatial and related attribute information (Smith et al, 2001). Smith et al (2001) recorded experiences similar to the ones found in this study in a fleet management application:

> *"It may be technically possible to position a mobile phone to within 10m of it's true position, but if this position information needs to be used in conjunction with a map of a larger resolution (i.e. a small scale map representing a country), the geocoding process is likely to result in incorrect results. The same result would be achieved with coarse positioning accuracy and large scale maps."*

Mountain and Raper (2001) express a view where LBS providers are at mercy of data providers whose data may be outdated, inaccurate or wrongly geo-referenced. Experiences on the Norwegian market have led NetCom to improve their presentation of a position both in terms of accuracy and in usefulness of the information. When there is a demand for higher accuracy, network operators should theoretically invest in positioning technologies with increased accuracy. The following sub chapter describes what is being done on the Norwegian positioning technology market and why.

6.1.5 Improvements of existing technology:

Maybe most importantly the lack of governmental push for increased accuracy in GSM positioning, slows down improvement of positioning technologies in Norway. There are no similar demands to the US E911 (www.fcc.gov), even though it is decided that Europe shall have a standard emergency number - 112. There is going to be demand for positioning a mobile caller to the service, often called enhanced 112 (E112). The accuracy demand for E112 is much lower than those of E911. This is seen as a very positive thing for Norwegian network operators as the US demands are not met and operators have suffered great loss in technology investments. NetCom (2003) says that such high demands are not economically defendable since the LBS do not give enough income yet. Telenor could inform that E112 demands are met with the accuracy represented in CGI+TA technology.

With little governmental pressure, technology can be developed in line with income from LBS. The focus today is to improve the existing technologies with information available in the network and in tools such as radio planning (Telenor, 2003) (NetCom, 2003). Helgesen (2002) explains that accuracy in CGI+TA positioning can be improved by doing multiple positioning requests and comparing them to each other. The multi path propagation problem is marginalized when positions from different requests are used to give the statistically most likely position of a subscriber. The problem is that response time is increased. Response time is normally between 2-8 seconds and 10 positions will take about 50 seconds, which is too long (Telenor, 2003)(Helgesen, 2004).

Both network operators plan to make use of A-GPS in some years, but seem to avoid investments in other new technology. NetCom has considered using E-OTD as Cambridge Positioning Systems (www.cursor-system.com) has found a way to implement the technology without need for Location Measurement Units (LMU).

Investment costs are therefore much lower, but missing support for E-OTD in today's GSM terminals was the deciding factor for not using this technology (NetCom, 2003). Low investment-will for expensive GSM positioning technologies may be described by the coming UMTS network. This is the next generation network for telecommunication, and will take over for GSM. Even though it may take some years before we see a significant coverage, Network operators are reluctant to invest in expensive positioning technology that will be replaced by new UMTS-specific positioning technologies.

6.1.6 Accuracy demands per service type

As understood through earlier discussions and supported in Ame Info (2003), accuracy of the positioning technologies dictates what kind LBS can be deployed. Manual input from subscribers to add contextual information or increase accuracy, often called self-location method, can help support certain LBS (e.g. 1881 Navigation service) when there is a lack of accuracy in the infrastructure. Such solutions, however, are not optimal implementations. The obstacles for increased accuracy are costs, time to market and penetration (Ame Info, 2003). Low-accuracy technologies are employed on the current market, and are available to all phones. Mid-accuracy technologies will not only represent investment costs for operators, but also imply software changes for terminals, whilst high-accuracy technologies require hardware change in terminals as well.

Low-Accuracy technologies
Technologies such as CGI and CGI+TA are used for most LBS on today's market. Some LBS would clearly benefit from increased accuracy and would be implemented differently. Benefits are shown in discussions above, concerning Taxi and 1881. With increased accuracy, the nearest taxi service could be found without choosing between three possibilities, and 1881 navigation could be managed without self-location.

Mid-Accuracy
The role for technologies like E-OTD and UL-TOA is found in LBS needing the next level of accuracy (Ame Info, 2003). While these technologies might represent too low exactness for demanding Navigation Services, they should be good enough for LBS like E112 and tracking.

High-Accuracy
A-GPS enables a set of rich LBS that according to Ame Info (2003) subscribers are willing to pay for. Examples of such LBS are navigation, enhanced emergency services and pin point services.

Sometimes, institutions cannot present sufficient information through LBS. Trafikanten (2002) informed that they were planning a location based travel assistant with aid from Ugland IT. They found that an accuracy of 500m, as can be the result of CGI+TA, would not support this LBS properly. In some urban areas, there are several stops for tram, sub-way or buses within an area of 500m. Since the LBS was conceived to become too complex as a result of multiple interactions choosing the proper transport, also resulting in higher subscriber-costs, further developments were dropped.

Accuracy demands are not always absolute; most experiences are that service providers will take whatever accuracy they can get (Telenor, 2003). An emergency service is far better off with 500m accuracy than no positioning at all. Since service providers cannot force network operators to provide increased accuracy, investment in positioning technologies is a based on generating increased income for network operators.

Vehicle navigation systems are generally considered to require a high degree of positioning accuracy, as different roads, ramps and sections of multi-level (altitudes) highways often are positioned close together (Dennis, 2003). Vehicle navigation therefore require technology with higher levels of accuracy, and uses GPS in most situations. Such LBS are not implemented using GSM positioning, but Fleet steering and 1881 navigation are approximations that could be seen as first generation navigation services on GSM. Maybe these will generate a push for positioning technologies with increased accuracy in the future.

6.1.7 Precision

There is a strong dependence between precision and accuracy. Since precision denotes how often we get positions within certain accuracies, it is understandable that we increase precision when decreasing accuracy. As it is beneficial with technology that increases both of these values, an assessment of the technologies would be useful.

Precision is commonly measured in percentage within the field of GSM positioning. The FCC mandates requirement of 100m (67%), is subsequently a demand for accuracy within 100meters for 67% of all calls – precision of 67%.

The quality of service parameter for precision in Telenor is set to 90%, and accuracy is measured with this percentage. It is not unusual to measure precision at 67% which can yield a different set of accuracies, often much higher. With a large spread in accuracies when choosing a lower precision level, varying results are found by the LBS (Telenor, 2003). Seen from a subscriber's perspective, this would be experienced as if positioning accuracy was lower and more random. As precision illustrates stability in the positioning technology, low precision may remove subscriber's trust in the truthfulness of the position.

A way of improving accuracy and precision is combining positioning technologies to form hierarchical and overlapping levels (Hightower and Gaetano 2001). Since precision and accuracy is affected by topography, and technologies are affected differently, such combinations can help provide positions of even precision.

The importance of precision is not yet portrayed by Norwegian network operators, but Telenor is tracking precision constantly and test-positions are done every 5th second. This data has not been analyzed, but they are gathering data in case precision becomes an important issue for times coming (Telenor, 2003).

It would be interesting to do an assessment on each of the technologies focused in this study, but it has been difficult to find information on how precise the technologies are and the way it varies with different situations.

6.2 Topography

Normal categories of topography in relevant literature (Lacy et al., 2001) (Steinfield, 2003) is between indoor, urban and rural areas. Topography can be seen as part of a subscriber's context. When moving from the context of urban environments into the context of rural areas, contextual mobility also includes movements between areas with differently shaped landscapes. The way positioning technologies perform and how accurate a spatial position can be found is dependent on the topography. New buildings, new base stations and removal of trees are examples of change that make the topography contextually mobile.

6.2.1 Rural and Urban areas

Normal influences from topography to positioning technologies are reflection of radio signals, blocking radio signals and the density of mobile Base Stations in the area. Field tests on CGI+TA in Gudbrandsdalen, conducted by Telenor showed accuracy decrements of up to 70% compared to accuracy in urban areas. The most common error source was reflections from the demanding landscape. These reflections have no effects on the CGI values, but gives wrong output of Timing Advance values since the signal travels longer than necessary before it reaches the subscriber. The case was normally that the subscriber was situated inside the TA and the signal reached the subscriber after being reflected by an object further away (Telenor, 2003). Results are that the subscriber often is estimated at a location further away from the base station than actual position. When transferring this example to the urban setting, one can reason that buildings can give similar reflection to the ones measured in Gudbrandsdalen. The main difference is the frequency of base stations that makes reflections less noticeable. Accuracy of the network based technologies is dependent on the frequency of base stations, accuracy is therefore much better in areas with more base stations (NetCom, 2003)(Mountain and Raper, 2001). There is restriction to how many subscribers can be connected to one cell, and in order to serve the high number of subscribers, network operators put large numbers of Base Stations in urban areas with high population. This decreases the cell size and gives great enhancements to

CGI based positioning. In fact, all network based technologies focused in this thesis except AOA gain accuracy in urban areas (Lähteenmäki, 2000).

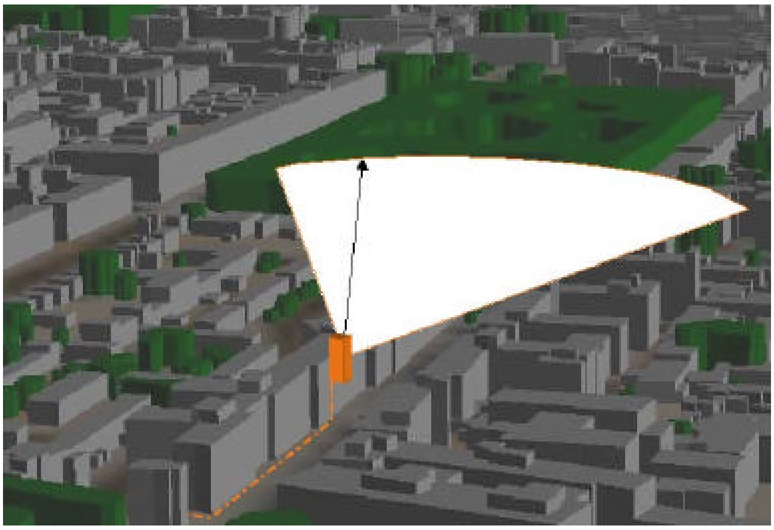

Figure 14: Illustration of a typical topographic environment, and a location found by CGI technologies. The brown box is base transceiver station and the white area represents the area that the subscriber positioned can be found. Walls, buildings, trees, etc can affect performance of different technologies.

Applying logic

Logic can be put in the positioning technology to improve accuracy despite topographical errors, for example discarding positions with highly unlikely geographic occurrences. NetCom does this when a position is found over areas made up of water. The system simply corrects the position and gives a position that is in the closest area with dry land (NetCom, 2003), and operators usually get a better position. Contextual information is put into the positioning technology and the spatial positions are results of this information. The danger with this implementation is that application developers have to be aware of such corrections when using these positions in LBS. If the LBS is concerned with locating subscribers in distress, there is a possibility that this person is in the water. Another example is the tracking service offered by Falken, when the GSM network is used to track boats when stolen. Such applications may need to override this specific enhancement. NetCom (2003) discussed other possibilities as to enhancing accuracy by using the radio planning tool to provide logic to where subscribers live, where they travel and where they most probably is not located. Once again, being aware of which logical assumptions the system puts basis on is of importance when designing applications that use the positions.

Indoor coverage

A useful feature of GSM positioning is that it works indoors, provided there is network coverage. Subscribers spend much of their time in indoor contexts; either at home, on the bus, at work or in their spare time. It would be fatal for some LBS if they could not be accessed if a subscriber is inside a building. Indoor coverage is the problem of GPS and A-GPS. These positioning technologies give what is

conceived to be the best outdoor accuracy, along with potential worldwide coverage.
Although being the two most accurate technologies, they are useless for locating terminals that are inside buildings. While network based technologies work best in urban areas with concentrated populations and more Base Stations, GPS and A-GPS perform much better in rural, open areas when there is less obstruction. Ironically, GPS performs worst in the areas where network based positioning technologies work best.
France et al (2001) have plotted values of accuracy (y-axis) and usage environments (x-axis) for the different technologies, as can be seen in figure 15. The shapes on the figure show that there is no single value for each technology, but a range. France et al argue that irregular values are results of changes in environment and in network infrastructure constrains for these. Note that for all of these shapes, differences between positions are smaller (represented by a pointy right hand side of the figure) when in open areas. The reason is that there is less multi-path propagation (France et al, 2001).

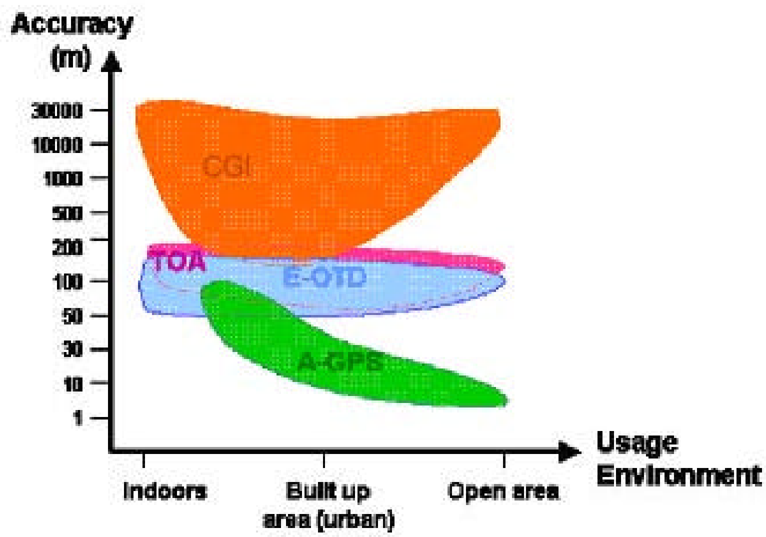

Figure 15: Mapping accuracy with usage environment (topography) for technologies. (France et al., 2001)

The dependencies between topography and performance between network based technology and GPS/A-GPS, make for a good combination where these solutions can complement each other. Telenor (2003) believes that A-GPS will be used in the Norwegian market in a couple of years, and they use GPS in some applications already. An example where the two technologies are used as compliments is in the 'Voldsalarm' application. Both GPS and CGI+TA positioning is implemented in a specially tailored terminal, and when a GPS position is not available the LBS locates a person with GSM positioning. NetCom has similar views of using a combination of technologies, especially considering the upcoming A-GPS and network based positioning (NetCom, 2003). NetCom argues that it is important that the fallback technology is as accurate as possible when topography makes A-GPS unavailable. A great difference in accuracy between two technologies supporting the same LBS may make the LBS unpredictable (NetCom, 2003). Table 19 depicts how topography affects different technologies, with basis in Telenor (2003), NetCom (2003), Lähteenmäki (2000) and technical characterizations from chapter 5:

Technology	Reflections(also called Multipath propagation	Satellite visibility	Density of base stations
CGI	No	No	Large
CGI+TA	Small	No	Large
UL-TOA	Large	No	Medium
GPS	Large	Yes	No
A-GPS	Large	Yes	No
E-OTD	Large	No	Large

Table 19: Affects of topographical disturbances on different positioning technologies

6.2.2 Relative demands by LBS

Although topography changes the attributes of positioning and some technologies work better in some environments than other, it is useful to asset topographical demands from the view of the LBS. Fleet-management services offered on the Telenor network, use CGI+TA and is affected by how positioning changes according to topography. Ironically, complaints about accuracy have come in urban areas, where accuracy and precision is best for this specific positioning technology, while positioning in remote areas was perceived as more than good enough (Telenor, 2003). When reflecting on why the LBS is perceived in this manner, Telenor came to the conclusion that it depends on expectations and different need for accuracy in distinct regions. By applying theory from chapter 3, the meaning of a spatial position is contextually mobile. When a truck is located in a vast area with few houses and subscribers, the information presented to a person trying to find out how far a driver is from his destination does not become considerably more useful if it is served at 300 meters accuracy instead of 1 kilometer. Importance for the fleet controller is in knowing which truck is nearest a location or approximately how long it will take for a truck to reach a destination. This is the practice of the institutions of transport companies, and is what the LBS should support. When doing the same positioning on a truck located inside an urban area, the picture is completely different. Small distances take a long time to drive and there may be several trucks within a much smaller area. Urban areas represent situations when accuracy demands are critical. Colibria (2003) depicts a similar view for the Kompis application. When positioning a person within a city, differences of 300 meters can be decisive for the subscriber, in example if trying to figure out which one of two neighboring houses the person is inside. The view of Colibria is that accuracy is not good enough in rural areas, but if you expect a friend to be in the city and get a reply that he is in another part of the country, this is often accurate enough. These two examples illustrate a higher demand for accuracy and precision inside rural areas, but other examples can easily illustrate a great need for accuracy in rural areas, one being an application meant to provide navigation information for drivers. Two exits 300 meters apart could lead to completely different destinations. For most LBS in today's market, it seems as if accuracy is far more important in urban areas.

6.2.2.1 Contextual reasons for varying accuracy demands

An analysis of the context can help describe the special and varying accuracy demands by LBS. The theory chapter explained differences in the meaning of space and place, and related this to spatial, temporal and contextual mobility. Using the friend finder as an example, spatial movement is meant to be captured by the application. A user of the LBS will relate to accuracy according to the purpose or context another person is positioned. Although very hard to capture, this context explains the mentioned variety of accuracy demands from of tracking services. If locating friends in a context where the purpose is to search for all friends in the contact list and then contact the nearest friend, accuracy demands are much higher for the friends that are nearer than those farther away. Friends located in other cities or remote places can be excluded from interest when their position is revealed, and for this purpose accuracy saying that the friends are out of town is enough. Since the subscriber has to compare the positions of friends that are nearby and possibly separate between two subscribers within 1km or even within 100m, a finer accuracy is needed for positioning friends nearby. Similar contextual relevancies were found in the fleet steering services. When a truck is in a context where there is little traffic, buildings or few other trucks, accuracy demands are low because e.g. 1km difference has not got that much implication for correct fleet steering. Accuracy demands in context of a city center are completely different and as little as 200m can be decisive for assuring optimal fleet steering. Distance in the context of a city gives much higher implications because it takes longer to travel the distance, there are more places to pick up and deliver cargo and there are more trucks to choose between. This illustrates that even though we are interested in spatial positions as output from the LBS, the meaning of the info is dependent on the place it represents or the context and purpose it is used for.

6.2.3 Indoor environments

Indoor environments reflect or block radio signals and may exclude certain positioning technologies. Indoor environments can also call for certain LBS with special demands for accuracy. Some technologies are more appropriate for outdoor environments whilst other have advantages for indoor positioning; GPS for example is a technology that does not work indoor.

Indoor specific LBS can be seen as LBS that have other topographical demands for performance in positioning technologies. Another view is that indoor environments represent demands for special behavior in the LBS. Due to the differences to other LBS and positioning technologies, indoor environments are discussed in further detail. Some of the mentioned positioning technologies give good results when used indoor, but for LBS specially tailored for indoor surroundings – other solutions may be better fitted:

6.2.3.1 Indoor specific positioning technologies

The term 'indoor specific positioning technologies' will be used to describe a set of equipment that is aimed to provide positioning within smaller indoor environments. These technologies are often seen as ubiquitous sensors. The goal of indoor technologies is to give support for fine-grained LBS, often specific for certain buildings. Examples are; deciding in which room a mobile terminal (and subscriber) is located, giving access to location specific menus, assuring connection or directions to the nearest printer etc.
It should be said that this type of positioning is not widely implemented, and is more directed towards future implementations. An interesting feature about indoor locating is that this area has been researched more within pervasive computing, and mostly on WLAN technology, hence targeting users of lap tops and PDAs rather than mobile terminals (Steinfield 2003, p. 5).

Indoor specific positioning technologies have a smaller coverage area, but often present better accuracy. Usually indoor specific positioning technologies find a subscriber's location as a result of the mobile terminal (and hence the subscriber), being in range of some sort of sensing technology. This feature makes them similar to the network based CGI positioning where the position is given if a cell is known, implying that objects within that cell area in the same approximate position. The difference is that the indoor specific technologies have a range of 10m (Bluetooth) - 50m (WLAN), giving a much finer degree of accuracy – and lesser potential coverage area. The topography in the usage area is very different from situation to situation. Sometimes there will be many objects in a room that can disturb signals and change behavior of certain positioning technologies, and sometimes there are none.

Potential indoor techniques for LBS are amongst others; infrared, ultrasound, radio frequency, WLAN and Bluetooth. Common for all of these are that they are in large part operating in the unlicensed spectrum, thus enabling low cost as a result of no airtime cost and mass production (Steinfield 2003, p. 6). Positioning from these indoor technologies is often proximity based.
WLAN may be part of mobile phones in the future if a convergence between the two technologies happens. Radio frequency techniques have a good accuracy but the signals are affected by people and furniture. Ultrasound can give very good accuracy but there are no signs on the market that this technology will be found in mobile terminals in near future. Infrared and Bluetooth are the two only

technologies currently incorporated in normal mobile handsets. IR needs a visual line of sight and cannot function if the mobile terminal is in a subscriber's pocket, therefore offering a very low precision.

6.2.3.2 Bluetooth as indoor positioning

Based on the mentioned drawbacks I have chosen to focus on Bluetooth technology as representative for indoor location technology, but most of the characteristics of Bluetooth that will be presented in the discussion are similar to those of other indoor proximity technologies.

A key aspect with Bluetooth is that the sensing nature of the technology makes it a proximity sensor, meaning that the position is discovered when the mobile terminal is within 10 meters of a beacon. Bluetooth can be used in two manners:

Physical positioning
One solution is to use Bluetooth as a physical (spatial) positioning technology for smaller areas. This can be done by putting up several Bluetooth units covering overlapping areas within for example a building, resulting in a grid of Bluetooth zones much akin to that of GSM Cells. A positioning system can then find the spatial position according to which unit the mobile terminal is close to. This resembles the network based CGI technology, with the difference that the mobile network is not used and the "cells" are only 10 m of diameter, giving it higher accuracy.

Proximate positioning
The other solution is to put Bluetooth devices at objects or areas of interest, and not being concerned with a physical position. This solution works more in the fashion of; a subscriber is here right now, let's do something. Space is not focus for this kind of positioning, but place and context are. The positioning technology does not relate a spatial position with contextual information, it merely detects the fact that a subscriber is in the same context as the Bluetooth unit. The following examples provide two imagined LBS that utilize proximate positioning:

-A person walks past a Coca Cola machine and gets access to the shopping menu for that specific machine.
-A fast food customer turns on the Bluetooth device on her mobile terminal when entering the diner and gets instant access to the menu. If registered to a mobile payment service, the customer can place the order and pay without waiting for the waiter.

6.2.3.3 Implementations of LBS using Bluetooth

LBS implemented with Bluetooth positioning technologies are able to sense locations and places based on a subscriber's proximity to the place. This enables implementations that are based on automation where subscribers do not have to manually initiate the LBS. The classical example of an institution's practices is the silence in theaters. This practice has been assured by architecture and social norms, but LBS can also support this practice by automatically turning the phone to silent mode when entering the area. This can be automated with sensing technology that discovers proximity like Bluetooth. The nature of Bluetooth makes it better suited for detection of available LBS at certain locations passed by mobile subscribers. Implementations would not have to perform multiple positioning to check if two subscribers are proximate, it would be sensed by the positioning technology and sent to the LBS. This would have great implications if Bluetooth were to be utilized in friend finders. Queries such as locating the nearest friends are hard to realize because of the price per position, but when sensing proximate relations between two subscribers such queries can be automated and provide notifications to subscribers. For other LBS, Bluetooth would enable information about a place and the institutions it represents to be broadcasted to all the subscribers within the physical area that represents the place.

The low range of Bluetooth signals inhibits it as a positioning technology with a noteworthy coverage area, and therefore eliminates Bluetooth as a standalone technology. If used as an addition to a chosen outdoor positioning technology, it can help to provide for LBS that need a very high level of accuracy and in indoor situations. In this option a subscriber can get access to LBS as a result of being near an object that transmits Bluetooth signals.

6.2.3.4 Performance of other positioning techniques in indoor environments

"All GSM based positioning technologies function indoors" (Telenor, 2003).
CGI, CGI+TA, UL-TOA and E-OTD all function even though a mobile terminal's signal is obstructed by walls, as long as they are not blocked. Their position accuracies vary between the technologies, but none of them are accurate enough to provide full support for indoor specific LBS with high accuracy demands. However, most of a normal person's life in the western world is spent indoor, at least in urban settings. For that reason, general LBS need to function well when a subscriber is indoor as well as outdoor, and the way positioning techniques perform in indoor settings need attention. Descriptions below are just taken on basis of how the technologies are designed and for a concrete answer to these technologies' indoor performances, field tests are necessary.

CGI

Since Cell ID locates a mobile terminal merely from knowing which cell the terminal is within, its accuracy will not be affected by indoor environments. The precision may decrease seeing that network coverage often is lesser inside buildings. As a result of an inherently low accuracy in the technology, CGI is not appropriate for indoor specific LBS that acquire a high accuracy.

CGI + TA

When adding the timing advance parameter in CGI, accuracy is improved. As mentioned, TA is an estimate of how long it takes for a signal to travel between a base station and a mobile terminal and therefore representing a distance between the two. In indoor environments, there are added physical obstructions and there exists more elements that can reflect and change the signal. This decreases the correctness of the estimate and therefore inhibits accuracy. The degree of how much accuracy is affected by indoor environments is uncertain, but CGI + TA is potentially less accurate in indoor environments than in outdoor environments with unobstructed line of sight.

UL-TOA

Uplink Time of Arrival utilizes the time differences between 4 or more LMUs, In much the same manner as CGI+TA the time differences are affected by the geography of the surrounding environment, and therefore provide decreased accuracy inside buildings. Inaccuracies in time differences theoretically have a greater effect on UL-TOA than CGI+TA, since it is technology with higher expectations to accuracy and it computes position from time differences between several base stations. If signals from each of these base stations are reflected significant inaccuracies may occur, while CGI+TA uses Cell ID from one cell.
It is actually possible that a less accurate technology like CGI+TA may perform similar to this technology as a result of the affecting environment.

E-OTD

As similar to UL-TOA, E-OTD uses time differences between several base stations. Performance of this technology may decrease in indoor environments if there is much obstruction and reflection in the signals for the same reasons mentioned for UL-TOA. It is not necessary that signals from all of the base stations are affected by walls, and calculation from these may make up for inaccuracies from obscured signals.

A-GPS

The high accuracy of A-GPS is a good argument for using it for supporting indoor specific LBS with a high need for accuracy. Unfortunately, the need for contact with four satellites eliminates A-GPS as an indoor specific technology. Although it performs in cars and other light sheltered indoor situations, it does not work inside buildings with thicker walls. GPS repeaters can be mounted at the edges of buildings to direct the satellite signals inside (Hightower and Gaetano 2001, p 60), but this would require a great amount of infrastructure.

Angle of Arrival

Angle of arrival is like A-GPS very dependent on an unobstructed line of sight between signal sender and signal receiver. As the technology computes position from the angles of where a signal meets the mobile terminal, reflections altering the directions of these make the technology useless in indoor environments.

Performance

Technology	Indoor	Urban	Rural
CGI	Mod.	Poor/mod.	Poor
CGI+TA	Mod.	Mod./poor	Mod.
AOA	Poor	Mod./poor	Mod.
E-OTD	Mod.	Mod.	Mod./poor
GPS	Poor	Mod.	Good

Table 20: Topographical effects to positioning technologies.

Mod. = Moderate (Adapted from Lahteenmaki, 2000)

Modifications

Technology	Handset	Network
CGI	-	SW
CGI+TA	SW	SW
AOA	-	HW&SW
E-OTD	SW	HW&SW
GPS	HW&SW	SW

Table 21: Imposed change by technologies.

SW = Software, HW = Hardware. (Adapted from Lahteenmaki, 2000)

6.3 Cost

This thesis is interested in costs represented by network operators' investments in positioning technologies and subscriber costs in handset investments and price of positioning.

6.3.1 Subscriber Costs

There may be many future revenue models for generating income from use of LBS. Examples listed in Steinfield (2003) are; subscription fees for LBS, connection and airtime fees, content fee margins of the price of products ordered. The situation on today's Norwegian market is that 3rd party developers and thereby users of their LBS pay per position (Colibria, 2003). The situation is the same for use of those LBS offered by the network operators. 3rd party service providers get price levels from Telenor, decided by the volume of positioning they oblige to. The price per position ranges from NOK 0,20- to NOK 2,-. AN LBS like Kompis may get positioning for NOK 0,50 (Telenor, 2003).

Roaming

An issue that may inflict costs for an LBS on the Norwegian market is future roaming of positioning between different network operators. Colibria (2003) explains that lack of roaming capabilities between the networks exclude subscribers from their Friend Finder application. Subscribers with a Telenor subscription, using Telenor's LBS 'Kompis' cannot find friends with a NetCom subscription, and this inhibits use of the service.

For LBS that support important public institutions such as the Police or the fire department, roaming is especially important. No subscribers should be left or forced to pay a different price for these services because they have a special subscription.

In October 2003, roaming of positioning data was agreed upon between NetCom and Telenor, and will be available by the end of 2003. NetCom's reason to make a roaming agreement of positioning data, was to make their Buddy service more attractive. The price of positioning a Telenor customer from NetCom's buddy service is not yet decided. It is uncertain how this will be realized; as such roaming is new in Norway. Roaming of positioning data is, however, realized in England. Experiences from England, where there are four network operators, is that roaming is realized through location brokers. These brokers are companies selling positioning, from the different network operators, to service developers. Brokers are interested in their share of the income from LBS and therefore raise prices. We see here that although roaming between operators is advantageous for adoption and expands use of LBS, it may inflict price for subscribers as they may need to pay more for LBS. In a situation where roaming increases price when locating persons on different subscriptions, the actual effect may be that subscribers avoid this entirely and full service is fulfilled. Steinfield (2003) says operators should be careful with a "walled garden" approach, as this strategy has failed earlier in WAP portals.

How fixed price of positioning affects LBS

In 2002 there was a fixed price for positioning at NOK 5,- per position. In October 2003, price per positioning was based on how many position transactions the service providers foresaw in their applications. When asking Colibria (2003) how the price of positioning affected use and development of their Friend Finder application, he replied that "if positioning was cheaper, this would enable grouped queries on the whole friend list". Seeing the usefulness of locating the whole friends list, is easy in the following imagined example. A person walks through town on the way to a meeting, when he is notified that the meeting is postponed by 30 minutes. This is as a perfect moment to meet a friend for a coffee, but since there are only 30 minutes available the person needs to find a friend that can get to his location on short notice. By searching for nearby friends, his Friend Finder application goes through all the subscribers on his list and compares their location with his own, portraying a list of friends within 500m. The subscriber can then call the person(s) located within reasonable distance. A typical subscriber may have 10 friends in a list and would need to pay for 10 positions when querying locations for all his friends. Differentiated price settings is seen as an advantage in these kind of queries, for example by offering the subscriber a discount according to how many friends he positions at the same time (Colibria, 2003). Such price settings would also enable a new set of LBS - those that sense that two persons are near each other and can give notifications on the form “You just passed a friend”. Queries of this kind involves computing relative location (see chapter 6.1) and LBS consequently get high demands for the rate to which updating of position must be done. This frequent positioning is depended on a different billing scheme than is provided today (NetCom, 2003), and would be too expensive with normal fixed prices. Dependent on the specific demands for each application, realization of these LBS may depend on a lower price more than the extra 100meters of accuracy. Telenor is actually evaluating positioning that only use information that is available in the mobile network so that they can provide LBS with low cost per position but with lower accuracy (Telenor, 2003). Having the mobile terminal acquire which cell it is connected to at all time is an example of a cheaper way of getting position.

Context of price

Context is also important when evaluating cost of LBS. For LBS that provide information and functionality that is not of high value, subscribers will find that prices must be low. Subscribers will for example not be willing to pay NOK 10,- pr position if it is used for pushing commercials or other information they have not asked for. However, when using LBS to position stolen assets, or in contexts that represent emergency or safety needs, there will be a much higher tolerance for higher subscriber costs.

6.3.2 Network operator cost

Many of the proposed positioning technologies are not implemented and necessitate major investment by network operators and/or subscribers (Steinfield, 2003).

6.3.3 Technologies and cost types

Network based positioning technologies will have a higher investment cost for the mobile operators, when building out the infrastructure for positioning. As there is no need for change in the mobile terminals, device costs will be low. Low price of devices eventually benefits subscribers, and the potential for market penetration of LBS is higher since all existing mobile subscribers can use LBS. After becoming a consumer of LBS, subscribers may find that cost per positioning is higher for network based positioning. Network operators generate traffic from positioning and location information, and will probably want returns from their investment in building out positioning infrastructure. These build outs for network based technology are most likely going to be slower for those of the handset based technology. (Lacy et al, 2001)

Network Operators	Subscribers	LBS
High investment costs.	Low investment costs, higher cost per position.	LBS that acquire less positioning and are not especially tailored to a subscriber. Examples: emergency services, mass market services. Etc

Table 22: Costs for subscribers and network operators with network based positioning technologies

Handset based technologies represent higher cost for the subscribers and lower cost for network operators. Device manufacturers may get increased profits from sales of new mobile phones, as subscribers need to invest in new location-supporting technology. The investment costs for becoming an LBS user may inhibit market penetration and result in adoption only within certain segments where there is a genuine need or interest for LBS. Once choosing to become a user by investing in a new mobile phone, price per positioning should be lower for end users. Although some supporting technology needs to be built into the existing mobile network for some handset based technologies as well, operators are most likely to keep the prices down. This will increase use of LBS and generate traffic and income for operators. For LBS using handset based technology not dependent on the mobile network, such as Bluetooth, the positioning itself will most likely be literally of no cost to the subscribers. Build out for handset based positioning technologies will be faster than for network based (Lacy et al, 2001) (See figure 16).

Network operators:	Lower investment costs
Subscribers:	High investment costs, lower cost per position.

Table 23: Cost relations between subscribers and network operators for handset based positioning technologies

UMTS

With the arrival of next generation mobile network, UMTS, investment costs in positioning technologies will be lower. The UMTS standard will include accurate location capabilities, and the higher density of base stations compared to GSM networks will give accuracy levels in the range of (several) meters. (Beinat, 2001 p.3). It is important to consider that even though UMTS has positioning in its standards, and will give accurate positioning, this is dependent on expensive build out of UMTS infrastructure. According to the low density of UMTS base stations and the slow pace for expanding the density, Telenor (2003) argued that there will be at least two years before UMTS positioning can compete with GSM positioning.

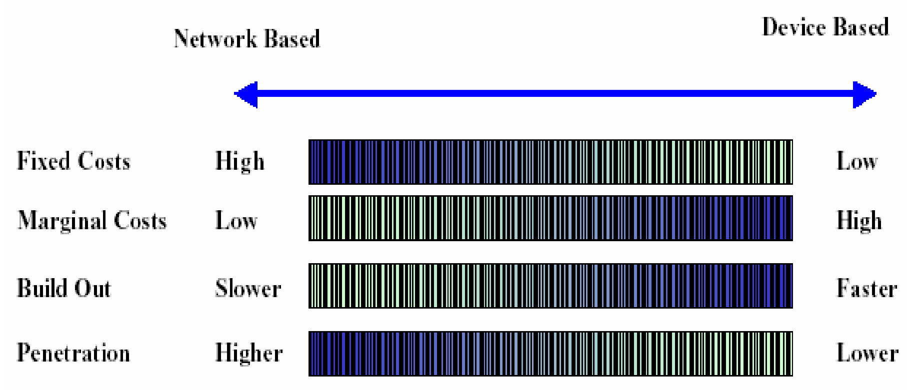

Figure 16: Illustration of costs represented by handset based- and network based-positioning technologies (Lacy et al, 2001).

6.4 Recognition

Recognizing the identity of an LBS user may be essential and easy in some technologies and represent difficulties in others. I general, network based technologies support recognition as a result of how they function, but with handset based and hybrid approaches it is not transparent how recognizing of a subscriber is supported (see table 24).

Technology	Recognition
CGI	Yes
CGI+TA	Yes
UL-TOA	Yes
E-OTD	Yes
GPS	No
A-GPS	Yes
Bluetooth	Possible but not necessarily

Table 24: Support for recognition in the technologies

Why recognition is important

Recognition is especially important for LBS that match subscribers with certain patterns of use, functionality, information etc. Hightower and Gaetano (2001) make a point of the need for automatic identification mechanism in applications that need to recognize or classify object to take specific action based on location.

The Friend Finder application provided by Colibria locates subscribers out of request from a subscriber. This LBS illustrates the necessity of recognition. The LBS must identify the subscriber requesting (person A) information about someone's (person B) location and check that person A is a registered user. The LBS must also check that person B is registered and has agreed to be positioned by person A, because of privacy concerns. If utilizing a technology that does not support recognition, this LBS is hard to realize with the needed safety/privacy demands for controlling the positioning.

Recognition in E-OTD

E-OTD and A-GPS are technologies where much of the location computation is done in the terminal. Since the position is not given purely by the network, can recognition of subscribers with these technologies be done? This depends on how position is utilized. When subscribers take benefit of the mobile network to access LBS, recognition is possible. Another question that was raised during the study of Friend finders was whether it was possible to locate another person via E-OTD and A-GPS technologies. As said in chapter 5.3.1, E-OTD can be mobile station based and mobile station assisted. When directing this question to (Telenor, 2003) assumptions were that both solutions are to be solved with mobile originated positioning requests. In practice this means that positioning must be done by the person carrying the mobile terminal, and is not done by another person or mechanisms in the network. E-OTD has consequently been said to give subscribers more control of when and by whom positioning can be done, giving increased privacy. In the question of support for friend finder applications, Telenor says that it is not a problem to implement a method that ensures that A-GPS and E-OTD can be initialized from the network side. Although this is not how positioning is planned in the technologies, this ensures support for friend finders.

Recognition in Bluetooth

The problem regarding recognition in Bluetooth is that the technology operates in the unlicensed spectrum, allowing everyone to make LBS based on the technology. Bluetooth positioning can be done with and without recognition and, depending on the wishes of providers. If mobile network operators would make an indoor micro localization system, they would most likely implement recognition so as to check if subscribers are customers etc. In an imagined situation where an independent company like Coca Cola utilizes Bluetooth for positioning a person's proximity to a vending machine and thereafter giving the person special offers and access to a shopping menu, recognition may not happen. There are several ways of looking at this, one being that Coca Cola probably want to reach all customers independently of their status so that they can sell more products. Coca Cola may also want to access pre-specified preferences stored by the person in his handsets, so as to give the person a tailored offer. In offering subscribers a way of reserving themselves from annoying LBS, Norway 's Personal Data Act (Personvernloven), if taking special considerations to these situations, may actually be the only protection other than turning off your own Bluetooth device.

Invoking LBS upon recognition

The way a location is given - dependent on the chosen positioning technology, determines how an application can be implemented and used. D'Roza and Bilchev

(2003 in Steinfield, 2003) classify LBS according to the way the positioning technology locates the subscriber:

1. "(…) those that are requested by subscribers once their location is determined…"

2. "(…) those that are triggered automatically once a certain condition is met (e.g. a boundary crossed)" (Steinfield 2003, p. 7).

The first category is easily identifiable as a pull service and is often connected to outdoor LBS, but the latter is clearly a push service. Although it is possible to do push- and pull services on both handset- and network based technologies, there are some differences to how easy this is done. Take for example the characteristics of indoor specific positioning technologies like Bluetooth. The proximity of a Bluetooth enabled terminal to some sort of Bluetooth device connected to a location based application is what gives a position, and can easily be configured to push services based upon proximity. This relates directly to category 2 above, with the condition being that the mobile terminal is within reach of the Bluetooth device.
Also on the CGI based technologies, push services are easily implemented. A practical example is welcome texts from foreign network operators when subscribers change cells originated from one country to another. At lower accuracy levels, push services can be implemented based on broadcasting the information within specific cells.

More fine grained location based push services and other more demanding, supported through technologies akin to E-OTD and A-GPS, represent complexity because of the way detection of locations are done. This situation calls for a constant positioning of the mobile terminal with cross-reference to points of interest.

6.5 Application of the capture model

The LBS market is not mature, and most of the LBS analyzed in this thesis are relatively simple, without the basic thought that positioning is to be a natural end point in other useful content services. Rather, position is used as a goal or an LBS in itself (Colibria, 2003) (Telenor, 2003). The LBS are not complex, part of a larger system, part of daily lives, nor rooted in institutional terms.

Because they are not rooted in institutions and context relevant for the LBS are not defined in institutional terms, the capture model is hard to make useful for development of LBS. According to Agre's (2001) theory, today's LBS are within those types that can benefit with the alternative to the capture model. This alternative is; capturing aspects of the environment that can give rough alternatives for institutional variables. Environmental aspects captured are the position in space and geographical landmarks. Further, it seems as today's Norwegian LBS are not meant to give subscribers meanings of place in the form of architecture, institutions and practices. Rather, the picture is that several institutions are put into several contexts by making the institution accessible through mobile phones, thereby introducing practices for doing things in many places. Agre's (2001) framework is aimed at understanding the lives of subscribers, through the terms architecture institutions and practices. This framework is useful when developing LBS that are complex and take part in subscribers' lives.

6.5.1 MiniGps

An example of an LBS that captures place in the meaning of architecture, institutions and practices is MiniGps (Psyloc, 2003), a downloadable java application for symbian phones. The LBS offered by MiniGps can draw benefit from the capture model. The application allows subscribers to register cells in the mobile network, and thereafter represent these cells with actions. In this implementation, the mobile phone will automatically perform the specified events when subscribers carrying them pass areas covered by the registered cells. The way context is captured in MiniGps is that the subscriber specifies actions for specific positions and stores the information on the phone. This way of capturing context is not very interesting in itself; it does not presuppose any institutions or practices for how context is captured. However, the nature of the application makes the model interesting. Specifiable actions based on spatial positions enable the application to take part in subscribers' everyday lives. MiniGPS can represent communication that is part of institutions and recognize practices imposed by places. The application illustrates important aspects of context that can be captured by the capture model. There are, off course, limits to how the context of places can be captured in an application than only uses spatial positions. Obvious limitations is capturing fluid contexts that change over time or that emerge sudden, and contexts that cannot be represented by spatial positions.

For places like church, theater, hospital and similar, MiniGps can put the mobile phone to a modus that restrict the use. Instead of using the architecture, an institution's practices can be mediated by the LBS. The implementation can only represent places by comparing spatial positions with stored events that are matched with the positions, and so architecture is not represented as decisive for the context in MiniGps. A consumer may indicate that the application shall turn the phone to silent mode when connected to cells covering his office or have the phone automatically send an SMS to family members when driving past specified cells on the way home. The cells from base transceiver stations are physically located in space, but they are not places until a consumer has told the application to relate the location with an explicit behavior. In this way, the positions are symbolic and not physical and the positions represent contextual situations such as at work, on the way home and similar. It should be mentioned that MiniGPS is dependent on a lot of input from subscribers, but each time the subscriber specifies behavior, he expands the LBS to automatically perform more of the tasks that traditionally are done by the subscriber himself.

6.5.2 Using the capture model to capture place

Agre (2001) suggests that restructuring the activity itself makes it easier to capture relevant aspects of the context. The following is an example of how the capture model can be applied for getting the context and represent places or activities in the MiniGps application

Analysis
A person utilizing the MiniGps application for representing places and activities of daily life, should analyze his activities and break it down to smaller elements. Examples of smaller elements are; arriving work, going home from work, at the cinema, in meeting etc.

Articulation
The smaller elements should be articulated into a grammar that represents sequences of action for the institutions they represent. Arriving work can represent rules such as giving notice to coworkers or downloading mail. Going to the cinema or a meeting usually represents a situation where the mobile phone is to be switched of or put on silent mode.

Imposition
The grammar that articulates the events and actions is imposed to the everyday life of the institution. For a person going home from work, imposition can be that family members are notified that the person on the way. Grammar imposed in everyday life can have effects on the architecture, for example when imposing a rule saying that customers should not steal any merchandise, theft detection systems are installed in shops.

Instrumentation
A system of social or technical mechanisms can be designed to install practices that represent the activities that MiniGps was meant to capture. Instrumentation in the examples given above can be sending an SMS to family members when passing specific areas on the way home from work, turning of the phone when entering the spatial area of the theatre or putting the phone to silent mode when within meeting rooms.

Elaboration
The captured activity can be use or misused for many purposes. An example of using the activity for another purpose is; logging automatically sent SMS messages and thereby monitor a person's activities and movements.

Strengths of the capture model

This example show that the capture model helps clarify context and represent it in context aware applications. LBS are context aware in the degree that they capture context out of spatial and relative positions, and thus can only capture a part of the context even when utilizing Agre's (2001) capture model. The main difference between capturing position as a cue for context and the capture model is that the capture model is able to represent human and institutional behavior. Implementations of LBS thus become more tailored for the subscribers with the capture model. Situations for which the capture model is not especially useful is in applications that has a specific meaning in it self, such as finding an ATM or a restaurant, and that therefore is not to be used for representations of human or institutional behavior.

During the research, conversations with Colibria (2003) showed the company's vision that all or many of the LBS presented in chapter 4 can be utilized and combined in one service. In this way, today's LBS can become natural end-points in larger content services, where one function is linked to another. Examples are that finding an ATM can become end-point of a shopping service, navigation a means to find a shop, or friend finders a way of alerting others that they are meeting in a specific shop. In this visionary future, the capture model can be used beneficially to help decide which applications should be linked together in larger services. Since the model helps capture human and institutional behavior and instrument it with representations in a content service, it can benefit in implementations of content services that utilizes many location based applications.

Chapter 7

7 Conclusion

The purpose of the thesis was to explore how positioning technologies in the GSM network supports LBS. Based on the hypothesis that one positioning technology differ from the other in regards of accuracy, cost and behavior in topographical environments, I have tried to explore how implementations of LBS are enabled by the characteristics of the positioning technologies. The chosen problem area was motivated by a lack of research that relates implementations of LBS to positioning technologies.

This thesis has mainly utilized theory from Agre (2001) and Kakihara and Sørensen (2002). Support for spatial, contextual and temporal mobility from Kakihara and Sørensen (2002) has proved helpful for analyzing LBS and has improved the general understanding of these. Agre's (2001) theoretical framework for mapping activities with places was found valuable as a tool for describing how implementations of LBS use positions. The framework has helped explore how institutions and place can mediate practices formerly given by architecture and institutions. Agre (2001) has therefore shown how mappings between activities and places decide how locations in LBS are used to support activities. The capture model can be used beneficially when capturing contexts related to places, even though these places are discovered by spatial positions. The capture model is relevant for LBS that are part of institutions, and results show that context in an LBS should be defined in institutional terms. For LBS not defined in institutional terms, Agre's (2001) alternative should be used; capturing aspects of the environment that can give rough alternatives for institutional variables – in this case spatial and relative positions.

7.1 Positioning technologies

The most normal positioning technologies for the mobile telecommunication network are CGI, CGI+TA, UL-TOA, GPS, A-GPS and E-OTD. Bluetooth positioning technologies was also included to give an example of an indoor specific positioning technology and show the significances of such positioning technologies. In the year 2003, positioning technologies used by the two Norwegian network operators; Telenor and NetCom, was CGI, CGI+TA and CGI with position enhancements.

CGI is the simplest of these positioning technologies, and uses the location of the handling base station. As CGI uses existing mechanisms in the standard GSM network it does not require any hardware or software change in the mobile phones. Investment and drifting costs are low for network operators, and should therefore keep subscriber costs down. The drawback with the positioning technology is that it has a low accuracy that is dependent on cell density. Field tests by Laitinen et al (2001) showed an accuracy of 328 meters at 67% precision in urban areas and 639 meters in suburban areas. An advantage with CGI is that performance does not deteriorate indoors or in areas with many topographical hindrances.

CGI+TA calculates the distance from the base station handling the call. The result is an improvement of the accuracy found in CGI. Field tests by Laitinen et al (2001) showed an accuracy of 283 meters at 67% precision in urban and 415 meters in suburban areas. Although Swedberg (2001) argues that the accuracy is between 100-200m, such results are dependent on a high density of base stations. CGI+TA also uses mechanisms in the standard GSM network, which keeps the price down although it is more expensive than CGI. CGI+TA works in all topographical conditions but accuracy worsens with geographical hindrances that disturb the signal and changes the TA value.

CGI with position enhancements uses the location of the handling base station, and applies logic derived from coverage maps that are available through radio planning tools. This is a solution developed by NetCom and is not part of any standard for mobile telecommunication. Accuracy is said to be 75-100 meters in urban areas, but with fewer base stations in rural areas it can reach 3 kilometers. The cost of the positioning technology is higher than CGI, but it is still relatively low as it uses data that already is available to the network operator.

Both Telenor and NetCom intend to increase accuracy of positioning in the near future and say that A-GPS probably is the best choice for future investments (Telenor, 2003) (NetCom, 2003). This is a technology that has complementing characteristics to the positioning technologies currently in use.

7.2 LBS

NetCom and Telenor offer LBS within information, safety, fleet steering, navigation, asset tracking and geographic routing of calls. Positions are in general used to give a contextual meaning for or about subscribers with high spatial mobility.

Information services

These services help subscribers find objects such as ATM's, liquor stores, Post offices, Taxies. Information services benefit from attaining positions in all topographic areas. However, as there are fewer occurrences of ATM's, liquor stores, Post offices, etc in rural areas, the information services are generally more beneficial in urban areas. Accuracy of today's positioning technologies is often lower than the density of the objects the information services locate. Implementations of information services are dependent on the cost for each position. Enhanced functionality with frequent positioning is not possible with high positioning costs.

Safety services
Location based emergency calls and violence alerting services are safety services currently in use. These LBS enable contact between subscribers and the institutions of safety, even when subscribers are located in remote areas. It is clear that these LBS are as important in urban areas as they are in rural areas. The difference between the two topographical areas is that urban areas call for higher accuracy in order to physically find subscribers located by the LBS. Safety services are benefited with any accuracy, but increased accuracy in the LBS eases the authorities' process of finding subscribers in distress. Cost of positioning is not a deciding factor for implementations of safety services as the high human value of the LBS.

Fleet steering
Location based fleet steering applications support transport institutions in performing their practices. A normal practice is to assign jobs to the nearest truck while assuring that the delivery is relatively in line with the trucks route. LBS simplify the process of finding the nearest truck and eliminate the need for constant contact with the drivers. As with friend finders, increased accuracy is needed in urban areas. Ironically, transport companies request increased accuracy in the area where accuracy is highest and do not complain about accuracy in rural areas. The reason is believed to be change in the positioning information's contextual meaning when shifting from urban to rural areas (Telenor, 2003).

Navigation
When used for navigation, an LBS can support any activity that is connected to finding a place. Practices for navigation will influence the way a navigation service is implemented, but most importantly practices may be changed as a result of having navigational assistance available at "all" times. Existing applications that support navigation has shown the need for high accuracy in the positioning. An LBS that gives navigational assistance with a 500 meter error margin will fail in usefulness for most subscribers. Implementations of location based navigation services may be dependent of the costs per position. Price per position must be cheaper for an LBS that is supposed to give constant and updated information about routes based on automatic updates of a subscriber's position.

Asset tracking
Asset tracking does not necessarily need high accuracy from the positioning technology. Low-accuracy solutions still give subscribers assistance for their activities. However, as with most other LBS, increased accuracy would be

beneficial and enable implementations with much more detailed information about locations. In a situation where asset tracking is used to position a stolen car, cost of the position is not decisive for implementations of LBS if subscriber prices are around NOK 5,-. When used for deciding many friends' whereabouts, the price per position will matter much more, and must be lower. The topography demands are as varying as the geographical usage area for asset tracking. Sometimes assets are located within cities with many buildings and reflections of the radio signal (urban areas), and other times they are in remote locations with little interference but less telecommunication infrastructure (rural areas).

Geographic routing of calls
Positioning the mobile phone and routing the call according to the position is useful for institutions with many departments or offices. Examples of such institutions are the Police, Post offices and large companies. Geographic routing of calls is a service with little need for accuracy, as two departments typically will be further away than the error margin of today's positioning technologies. The decreased number of departments of an institution in rural areas makes a lower accuracy possible, and changes in topography therefore have little impact on the service. Future versions of geographic call routing, such as an LBS that route a caller to the nearest driver based on the subscriber's position, may need increased accuracy.

7.2.1 Limitations in positioning technologies and how implementations of LBS are affected

Accuracy
Although accuracy is more than good enough to support services like location based weather forecasting, many LBS need increased accuracy. Positioning technologies with inadequate accuracy can lead to implementations of LBS that are based on workarounds. Application developers must evaluate the way location information is presented to subscribers. Presentations with less accuracy than the position, is in fact similar to using a technology with less accuracy. Experience from the case study is that in situations where positioning technologies cannot provide the accuracy that an LBS requires, more manual input is needed from subscribers.

Topography
The topography of the area where an LBS is used influences how the technologies perform. Normal reasons for decreased accuracy in certain topographies are multi-path propagation and blocking of signals. Technologies that compute position based on timing (CGI+TA), time differences (E-OTD) and angles of radio signals (AOA), are especially affected by topography. Further, the most accurate positioning technology, A-GPS, is ineffective inside buildings as satellite signals are blocked. The way these topographical differences affect LBS, is hard to give absolute answers to. Occurrences from the case study show that

subscribers of fleet steering and friend finders expected and needed more accuracy in urban areas.

Cost

Although costs of investing in new technology were assessed, focus in the research was on subscriber costs. There is no final dependency between a positioning technology's characteristic and subscriber costs of using an LBS. However, positioning technologies that represent high investment- and maintenance costs for network operators may increase the price per position for subscribers if network operators are to get a proper return on investments. In today's market, income from LBS is generated from subscribers that pay a fixed price pr position. High subscriber costs per position may inhibit implementations that use frequent positioning.

7.3 Relation to existing research

This thesis illustrates that LBS have varying needs for characteristics in positioning technologies, depending on the LBS' significances and how it is implemented. These findings are in line with France et al. (2001). They conclude that no single positioning technology has advantage over others and that technological, economical and quality differences are found. On this basis France et al. (2001) declare that selection of positioning technologies should be concerned with meeting subscriber requirements since the ultimate aim is to provide subscribers with practical and useful LBS.

The current study shares the views of Beinat (2001) on the topic of how investments will be influenced. Cell ID and enhanced versions of it will be the main technology available for the coming years, possibly expanded with A-GPS. Reasons are not only high investment costs, but also in the need to introduce interoperability and roaming of positioning.

7.4 Implications

For people that work in the field of LBS and provision of positioning technologies, this work can help illustrate issues that need attention. When developing LBS, application developers need to be aware of the accuracy, price strategies and topographical effects of positioning since implementations to a high degree depends on these factors. This thesis does not give a complete answer to how the technology affects development of these LBS, but provides specific situations that are believed to be important examples of such affects. Network operators may also benefit from issues presented in this study. Both price schemes for subscribers and investments in existing and new technology are dependent on an understanding of how position is used in implementations of LBS.

7.5 Further research

The results from this research indicate how the characteristics of positioning dictates the way LBS are used and developed. It is important to bear in mind that findings in this study is relevant to the setting in which the research was conducted, in terms of market, technology and LBS. Considering the case study as research method, and my interpretative philosophy, it is also difficult to generalize the findings of this study. This should be considered when applying my results to other situations. Real environments pose many uncontrollable factors and so do human subscribers. Due to time constrains and the chosen scope I have not done any actual tests on positioning technologies in the topographical environments described in the thesis, nor have I done surveys that include the views of subscribers. Such research could have been very interesting and possibly yield different results than my approach. Interesting further research would be to approach subscribers of specific LBS and discover how they utilize the LBS. Further, a study that tests situations from the case study with other technology, especially A-GPS, is highly relevant. Through such testing, a better foundation for comparing the technologies can be given. Combinations of CGI+TA with A-GPS could be tested to find how two distinct technologies are able to support each other in situations where one has disabilities and the other does not.

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